S. HRG. 103–563

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

HEARING

OF THE

COMMITTEE ON LABOR AND HUMAN RESOURCES UNITED STATES SENATE

ONE HUNDRED THIRD CONGRESS

SECOND SESSION

ON

EXAMINING PROPOSED LEGISLATION TO AUTHORIZE FUNDS FOR PROGRAMS OF THE NATIONAL SCIENCE FOUNDATION

MARCH 23, 1994

Printed for the use of the Committee on Labor and Human Resources

U.S. GOVERNMENT PRINTING OFFICE

77–815 CC WASHINGTON : 1994

For sale by the U.S. Government Printing Office
Superintendent of Documents, Congressional Sales Office, Washington, DC 20402
ISBN 0-16-044416-0

S. HRG. 103–563

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

HEARING

OF THE

COMMITTEE ON LABOR AND HUMAN RESOURCES UNITED STATES SENATE

ONE HUNDRED THIRD CONGRESS

SECOND SESSION

ON

EXAMINING PROPOSED LEGISLATION TO AUTHORIZE FUNDS FOR PROGRAMS OF THE NATIONAL SCIENCE FOUNDATION

MARCH 23, 1994

Printed for the use of the Committee on Labor and Human Resources

U.S. GOVERNMENT PRINTING OFFICE

77–815 CC WASHINGTON : 1994

For sale by the U.S. Government Printing Office
Superintendent of Documents, Congressional Sales Office, Washington, DC 20402
ISBN 0-16-044416-0

COMMITTEE ON LABOR AND HUMAN RESOURCES

EDWARD M. KENNEDY, Massachusetts, *Chairman*

CLAIBORNE PELL, Rhode Island
HOWARD M. METZENBAUM, Ohio
CHRISTOPHER J. DODD, Connecticut
PAUL SIMON, Illinois
TOM HARKIN, Iowa
BARBARA A. MIKULSKI, Maryland
JEFF BINGAMAN, New Mexico
PAUL D. WELLSTONE, Minnesota
HARRIS WOFFORD, Pennsylvania

NANCY LANDON KASSEBAUM, Kansas
JAMES M. JEFFORDS, Vermont
DAN COATS, Indiana
JUDD GREGG, New Hampshire
STROM THURMOND, South Carolina
ORRIN G. HATCH, Utah
DAVE DURENBERGER, Minnesota

NICK LITTLEFIELD, *Staff Director and Chief Counsel*
SUSAN K. HATTAN, *Minority Staff Director*

CONTENTS

STATEMENTS

WEDNESDAY, MARCH 23, 1994

ADDITIONAL MATERIAL

REAUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

WEDNESDAY, MARCH 23, 1994

U.S. SENATE,
COMMITTEE ON LABOR AND HUMAN RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10:01 a.m., in room SD–430, Dirksen Senate Office Building, Senator Edward M. Kennedy (chairman of the committee), and Senator Barbara Mikulski, co-chairing.

Present: Senators Kennedy, Mikulski, and Gregg.

OPENING STATEMENT OF SENATOR KENNEDY

The CHAIRMAN. We will come to order.

Today's hearing is being chaired by Senator Mikulski and myself, and we are delighted to have the opportunity to have this hearing on the reauthorization of the National Science Foundation.

When Congress originally passed this legislation in 1950, they aptly called the new entity a foundation, not an agency. In the half-century since then, research supported by the NSF has indeed served as the foundation of national progress in science and technology. It laid the basis for our modern high-tech industries and our research universities, and they are the envy of the world.

Laboratories and industries depend on technically trained people. The National Science Foundation's programs have played a leading role in educating the workers, scientists, and engineers, who maintain our economic growth.

As the need for research and growth has changed, the National Science Foundation has grown and changed, too. In 1968, this committee adopted legislation to enable the Foundation to support applied research. In 1976, we created the Foundation's office of Small Business Research and Development, to support cutting-edge research in technology-intensive firms. This office became the model for the highly successful Small Business Innovation Research programs throughout the Government.

Congress has also strongly supported NSF programs to improve education in mathematics, science and engineering from kindergarten through graduate school. The Excellence in Mathematics, Science and Engineering Education Act of 1990 directed the National Science Foundation to support initiatives for the system wide improvement of science education.

The National Science Foundation budget has grown as well. Today we are discussing authorization levels of more than $3 billion as an investment in research and education.

The world has changed dramatically in the 5 years since we last reauthorized the National Science Foundation. The Cold War has ended. The Nation's economic leadership is increasingly challenged by other countries, and often they have used our research to create new commercial products of their own. Our high school and college graduates worry about finding jobs that pay a living wage. The rapidly changing global economy is producing serious dislocations here at home.

In the crisis of the moment, it is easy to overlook our long-term interest. Today's basic research and education are the building blocks of tomorrow's economic success. In legislating on the National Science Foundation, we must plan ahead well enough to be sure that the Foundation's programs provide the knowledge and trained people we need to lead the Nation into the next century.

I commend my colleague, Senator Mikulski, for her leadership in stimulating consideration of these vital issues. I look forward to the testimony of our witnesses and to working with the committee and many others in Congress to see that the NSF continues to play its essential role in maintaining our leadership in science and technology.

Senator Mikulski.

Opening Statement of Senator Mikulski

Senator Mikulski. Thank you very much, Senator Kennedy. It is a delight to co-chair this hearing with you as a member of the Appropriations Committee, which has generated so much discussion on my views of science funding.

I believe Dr. Lane and others know my views, and I am going to ask unanimous consent that my full statement go into the record, acknowledging that we have a vote at 11:30. I think it is more important that we hear from Dr. Lane and the other witnesses.

I look forward to working with you on the reauthorization.

[The prepared statements of Senators Mikulski and Pell follow:]

Prepared Statement of Senator Mikulski

Good morning. The committee will come to order. Today we meet to review the programs and policies of the National Science Foundation.

As everyone here today knows, last year brought a great deal of change in the Federal Government's approach to science policy. My appropriations subcommittee, which funds NSF, is at the forefront of advocating that change—to focus more of our scarce research dollars to accomplish important national goals that will help our economy and its workforce.

The subcommittee's language last year on, "the Future of the NSF", sparked a great deal of discussion and debate—both pro and con—in the science community. It was designed to do so.

The United States of America has entered a new era at the end of the Cold War. Our greatest security threats are now more often economic than they are military ones. And the end of the national defense as a justification for so much of the science we've funded, since the end of the World War II, has led to high levels of anxiety in the academic research circles.

In a speech I gave recently at the National Academy of Sciences, I laid out the following principles which I believe NSF should follow to get ready for the 21st century:

—First, I'm promoting a change in the scientific community. It's a call for more NSF support for industrially oriented basic research, that is, more "strategic" research that would generate scientific knowledge to meet national goals. And at the same time, set milestones and ways of evaluating our efforts.

—Second, NSF should be structured less like a university and more like NIH. NIH is grouped around strategic areas to treat and cure diseases and illness.

Research institutes, such as NIH, range in research activities—from the basic aspects of life to the most applied activities that lead to stunning breakthroughs. Structuring research in this way allows us to think of initiatives in an organized manner and yet be flexible enough to move where scientific opportunity takes us.

—And finally, we must educate our scientists for workforce readiness. We must train our scientist and engineers, whether they are undergraduates or PhD candidates, so they are ready to work in strategic areas in the private sector.

I believe that there is a new paradigm emerging on how science is conducted and how it is organized. It's based upon the principle that science should lead to new ideas. Ideas lead to new technologies, new technologies lead to new jobs. All this enhances our standing in the global market.

I look forward to continuing the discussion today with the scientific and academic community through our panelists and the testimony of Dr. Neal Lane, the new Director of the National Science Foundation.

First, we will turn to Dr. Lane, for his remarks on what NSF has been doing and what NSF plans, to do and then we will move to the second panel.

Dr. Lane we are seeing a lot of each other these days. I welcome you before the Labor Committee today.

Dr. Lane is the former provost of Rice University and is the tenth director of the National Science Foundation. He is here today to share his hopes and his priorities for NSF.

You may summarize your remarks so we may proceed to questions before turning to the next panel. I look forward to your comments this morning.

Prepared Statement of Senator Pell

I thank the co-chairmen, Senators Kennedy and Mikulski, for holding this hearing today on the reauthorization of the National Science Foundation. As we move toward the 21st century our national commitment to science and scientific research must remain strong. Although the National Science Foundation is only a small part of our overall Federal research and development effort, NSF-supported projects have played a large role in our nation's continued advancement in the science and engineering fields.

I am delighted to note that the Administration shares this sentiment and has recommended increased funding for the National Science Foundation.

As Chairman of the Subcommittee on Education, Arts and Humanities, I am particularly interested in science education initiatives. I am aware that a significant portion of the Federal investment in science education at all levels comes from the Foundation, and I am pleased to know that the National Science Board Commission has recommended that NSF continue to make science and engineering education a priority. As I have said before, it is the people that are the source of technological innovation. We cannot afford to waste our human resources if we are to remain a world leader in science.

I would like to welcome all the witnesses to todays hearing and I look forward to hearing your testimony.

The CHAIRMAN. In that spirit, we will include the very expansive introduction of Dr. Lane, with his very extraordinary background and experience. The country is fortunate to have his services.

We are pleased to welcome Dr. Neal Lane to his first appearance before this committee.

Dr. Lane, who is a native of Oklahoma, holds three degrees from the University of Oklahoma. He has an outstanding research record in theoretical atomic physics and has published many widely cited papers in the field. Most of his academic career has been spent at Rice University, although he has held several distinguished visiting appointments.

In 1979, he served for a year as Director of the Physics Division at the National Science Foundation before returning to his position in the Physics Department of Rice University. In 1984, he left Rice to serve as Chancellor of the University of Colorado, at Colorado Springs, and returned to Rice to assume the position of Provost and Professor of Physics in 1986.

Dr. Lane, we look forward to hearing your views on the role of the National Science Foundation in the national research enterprise.

We look forward to your testimony, Dr. Lane.

STATEMENT OF NEAL LANE, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. LANE. Thank you, Mr. Chairman, Madam Chair, for the opportunity to testify today on the reauthorization of the National Science Foundation.

The President and Vice President have repeatedly emphasized investment in research and education as a critical ingredient in ensuring the long-term economic growth of the Nation. NSF is a focal point for many issues of concern to the Nation's science and engineering research and education enterprise, and our reauthorization provides a very important opportunity to discuss these issues.

Although I was confirmed by the Senate as director of the NSF only last October, my personal experience at the Foundation goes back about 15 years. In 1979 and 1980, while you, Mr. Chairman, headed up first a special subcommittee on the NSF and then later, the Subcommittee on Health and Scientific Research, I served as director of the Division of Physics at NSF. Having two terms of service at NSF, with a decade and a half between them, gives me a distinct perspective on the changes that have occurred at NSF as it has evolved over the years.

So I would like to take this opportunity to highlight some of the changes that have occurred at NSF in the 15 years since I first came to the Foundation. Then I would like to spend a few minutes examining some of the challenges that we are facing in the near future.

Since I left the National Science Foundation in 1980, the agency has been enriched by the establishment of three new directorates—in engineering, in computer and information systems, and engineering, and in social, behavioral and economic research.

When I first came to NSF, it was an agency of about 1,200 employees who processed about 10,000 proposals annually. Today, roughly the same number of employees process more than 30,000 proposals per year. During that period, our budget has more than tripled to its current level of $3 billion.

Not only has NSF grown dramatically, but our priorities have evolved as well. We have gone from providing about $30 million a year in 1980, for what was then the science and engineering education directorate, to allocating more than $500 million to its successor, the education and human resources directorate. I will talk about this change in some detail in a few moments.

When I first arrived at NSF, the Foundation was in the early stages of developing research centers where university and industry researchers could collaborate on problems of mutual interest. Today, NSF provides support for more than 160 centers serving as focal points for collaborative efforts jointly supported by States, industries, and academic institutions. Many of the research activities in these areas were in their infancy, or not even imagined, 15 years ago.

NSF today is larger; it is more diverse in its programs and activities, and it is better connected to the world outside of the research university than it was when I first arrived. These programmatic changes have strengthened the research community substantially, and now we are challenged to respond effectively to profound external changes in our society.

These external changes—the end of the Cold War, challenges to our economic competitiveness, demographic changes, and persistent budget deficits, to name a few—have had a number of important consequences for the research and education community.

For example, there has been a growing appreciation that federally-funded research and education cannot be insulated from larger national policy issues. This acknowledgment has been accompanied by a recognition of the importance of setting research priorities that are relevant to national goals. Future science and engineering research that relies on public funding must be justified in terms accessible to and valued by ordinary citizens.

It turns out that we have an outstanding case to make for public support. Our research and education activities do make a difference—but we need to make our case more forcefully than we have in the past. To those of us who are in daily contact with federally-funded basic research, it is obvious that it is having a positive impact. It is very evident to us that there are connections between our investments in basic research and the development of information superhighways, new manufacturing technologies, and a better understanding of global change, including the impact of human behavior on the environment. It is equally evident that the seeds of basic research pay large economic dividends in many areas.

Part of the difficulty we face in making our case to the public is the complexity of the discovery process. The personal computer that sits on desks in virtually every office and school in the country is an example. It does not occur to most of us to think about the personal computer as growing out of fundamental research in materials and mathematics and human factors and electronics. Nor does it occur to us that many of these advances were the direct or indirect results of federally-funded research.

Basic research discoveries and technology advances are the results of very complex processes that build on each other. When we fund research that seeks to advance our understanding of theoretical issues like the nature of matter or the origin of the universe, we are funding part of a discovery process that has very real implications for practical problems in areas such as signal detection, software development, communications technology, large-scale data management, and computer imaging.

One of the ways we are making these interconnections more obvious and more productive is by organizing research around strategic themes. These themes cut across traditional disciplines, making connections with national priority areas that bridge research fields and coordinate research within NSF and with other Federal agencies.

Our current budget request reflects a planning process that places increasing emphasis on research and education that is relevant to these national priorities. It is worth noting that of the incremental funds we are requesting for the coming fiscal year, more than three-quarters of that funding will go for research and education in the following strategic areas: global change research; high-performance computing and communication; advanced manufacturing technology; advanced materials and processing; environmental research; biotechnology; civil infrastructure systems; science, mathematics, engineering and technology education.

Of the $8 billion in the President's science and technology investment package, NSF accounts for more than one-third. The areas targeted for growth within NSF represent research fields that show promise for exciting near-term discoveries that also have near-term potential for application.

A more detailed discussion of our budget proposal is attached to my formal written statement, which I ask be included in the record.

The CHAIRMAN. It will be so included.

Mr. LANE. I would like to spend just a few minutes now discussing the last item on the list of strategic priorities—the science, mathematics, engineering and technology education activity. Within this area, we expect to invest $650 million next year in a number of programs that will lead to improving the education of the coming generation. This is because education in a very real sense is at the core of what we do at NSF. And in a rapidly changing world, we must focus attention on education that prepares people for work in an increasingly technology-driven environment. We must educate students in ways that provide them with problem-solving skills and that will be useful throughout their lives, regardless of the changes that technology brings to the workplace.

We have determined that it is worthwhile to develop alliances with the States in order to initiate bolder, more sweeping and sustainable improvements in their educational systems. To do so, we have formed partnerships with 25 States and Puerto Rico through our statewide systemic initiatives to design and implement comprehensive changes in their teaching of math and science.

NSF's systemic reform efforts are part of the administration's commitment to help States reform our elementary and secondary educational system through Goals 2000.

NSF's role as the catalytic agent for change has been very successful in generating interest in systemic change. As a result, we have extended this approach with our urban systemic initiatives, focusing on cities with large numbers of at-risk youth, and the rural systemic initiative, which addresses the special needs of economically disadvantaged rural regions.

We have also instituted an advanced technological education program, thanks to legislation sponsored in this body by Senator Mikulski, to promote improvement in secondary school curricula and instruction to help in the transition from school to the high-performance work force. This program recognizes that the highest-quality science, mathematics, and technology education must be provided to students who plan careers that do not involve 4-year colleges.

Finally, our alliances for minority participation, the AMP program, is making great strides in boosting the science, engineering and mathematics enrollment of under-represented minorities. When we began the AMP program in 1991, underrepresented minorities accounted for about 14,000 baccalaureate degrees in science, engineering, and mathematics annually. Our 15 AMP consortia, the oldest of which has been in operation just over 2 years, have already produced a net increase of 1,500 baccalaureate degrees to minorities.

I have spent a lot of time on education because NSF takes very seriously our responsibility across the spectrum of mathematics, science, engineering and technology education. We will not have a capable work force in the future if we ignore this responsibility now, nor will we have developed the talent required for the next generation of researchers, unless we pay careful attention to the policies—implicit and explicit—that guide science, mathematics, engineering, and technology education from kindergarten through postdoctoral work.

Let me conclude by briefly discussing a related issue, and that is the need to repair, renovate, and modernize academic research laboratories and instrumentation. NSF currently provides a little more than nominal assistance for infrastructure. To do more within our current budget would seriously skew NSF's highest priority, which is putting people first.

In September, NSF's next report on the academic research infrastructure will be available to provide an up-to-date assessment of the needs. I have talked with Dr. John Gibbons, Director of the Office of Science and Technology Policy, about the need to consider academic infrastructure issues on a Government-wide basis, and I have recommended that this issue be reviewed by the National Science and Technology Council.

Revitalizing the academic research infrastructure requires the cooperation of all Federal agencies, as well as the support of the States, universities, and the private sector entities that fund academic research. NSF has been a leader in supporting merit-reviewed infrastructure modernization activities, and we will continue our efforts to upgrade facilities while we work to develop a more inclusive approach.

In conclusion, Mr. Chairman, Madam Chair, I appreciate the opportunity to provide you with a summary of some of the important work being supported at NSF.

I look forward to working with you and your committee to make NSF's contributions to the Nation even more significant in the future than they have been in the past.

Thank you very much. I will be very pleased to respond to any questions you might have.

[The prepared statement of Mr. Lane follows:]

PREPARED STATEMENT OF DR. NEAL LANE

Thank you, Mr. Chairman, for the opportunity to testify today on the reauthorization of the National Science Foundation. The President and Vice President have repeatedly emphasized investment in research and education as a critical ingredient in ensuring the long-term economic growth of the nation. NSF is a focal point for many issues of concern to the nation's science and engineering research and education enterprise, and our reauthorization provides a very important opportunity to discuss these issues.

Although I was confirmed by the Senate as Director of NSF only last October, my personal experience at the Foundation goes back almost 15 years. In 1979 and 1980, while you, Mr. Chairman, headed up, first a special subcommittee on the NSF and, then later, the Subcommittee on Health and Scientific Research, I served as Director of the Division of Physics at NSF. Having two terms of service at NSF with a decade and a half between them gives me a distinct perspective on the changes that have occurred as NSF has evolved over the years. It's somewhat like going overseas for an extended visit. Even Though you might read the newspaper and generally try to keep up with what is going on, you are still subject to a bit of culture shock when you get back.

The culture shock I've undergone since taking over as Director has been mostly positive, but real. I'd like to take this opportunity to bring us all up to date on some of the changes that have occurred at NSF in the 15 years since I first came to the Foundation, then I would like to spend a few minutes examining some of the challenges we are facing in the near future.

Last October I came back to an NSF that was very different from the one I left in 1980. For starters, the agency has been enriched by the establishment of three new directorates—in Engineering, in Computer and Information Systems and Engineering, and in Social, Behavioral and Economic Research.

When I first came to NSF, it was an agency with about 1,200 employees who processed 10,000 proposals annually. Today, the same number of employees process more than 60,000 proposals every year. During that period our budget has more than tripled to its current level of $3 billion.

Not only has NSF grown dramatically, but our priorities have evolved as well. We've gone from providing about $30 million a year in 1980 for what was then the Science and Engineering Education Directorate, to allocating more than $500 million to its successor, the Education and Human Resources Directorate. I'll talk about this change in some detail in a few moments.

When I first arrived at NSF, the Foundation was in the early stages of developing research centers where university and industry researchers could collaborate on problems of mutual interest. Today, NSF provides support to more than 160 centers, serving as focal points for collaborative efforts jointly supported by states, industries and academic institutions. Many of the research activities in these areas were in their infancy, or not yet even imagined 15 years ago.

The NSF today is larger, more diverse in its programs and activities, and better connected to the world outside of the research university than it was when I first arrived. These programmatic changes have strengthened the research community substantially and now we are challenged to respond effectively to profound external changes in our society.

These external changes—the end of the Cold War, challenges to our economic competitiveness, demographic changes, and persistent budget deficits—to name a few, have had a number of consequences for the research and science education community.

We can no longer expect that Federally supported research will automatically increase every year. And there is a growing appreciation that Federally funded research and education cannot be insulated from larger policy issues. In recent years, the research community has grown to appreciate the importance of coordinating of Federal research, first through the FCCSET process and now in a much more comprehensive fashion through the President's National Science and Technology Council.

There is also an awareness that excellence in the evaluation and conduct of research and education is a necessary, but not sufficient, justification for the work we support at NSF. Finally, there is growing acceptance that setting research priorities that are relevant to national goals is crucial for developing the public support needed to maintain our work.

Many researchers who came of age in the post-war era grew up with the view that because science seeks to discover and understand the mysteries of nature—which is a positive good for society—then research has an intrinsic value that requires no further justification.

This view is changing to a recognition that while advances in knowledge and understanding represent a positive good to society, public support for our efforts requires that we justify these requests in terms accessible to, and valued by, ordinary citizens.

Simply because research is a public good, it does not follow that researchers can lay claim to every available discretionary dollar. Current budget pressures make it all the more important that the research community make its case to the public that the benefits of research serve to improve the quality of people's lives in concrete and understandable ways.

It turns out that we have an outstanding case to make. The research and education activities we support do make a difference—but we need to make our case more forcefully than we have in the past. To those of us who are in daily contact with Federally funded basic research, it is obvious that it is having a positive impact on our lives. It is very evident to us that there are connections between our investments in basic research and the development of information superhighways, new manufacturing technologies, and a better understanding of global change, including the impact of human behavior on the environment. It is equally evident that the seeds of basic research pay large economic dividends in many areas.

But we often erroneously assume that the effect of these investments is as evident to the public as it is to us. Part of the difficulty we face is the complexity of the discovery process. The personal computer that sits on desks in virtually every office and school in the country is an example. It doesn't occur to most of us to think about the personal computer as growing out of fundamental research in materials and mathematics and human factors and electronics. Nor does it occur to us that many of these advances were the direct or indirect result of Federally funded research.

Basic research discoveries and technological advances are the results of very complex processes that build on each other. Even in fundamental research areas there are multiple interconnections among our work. When we fund research that seeks to advance our understanding of theoretical issues like the nature of matter or the origin of the universe, we are funding part of a discovery process that has very real implications for practical problems in areas such as signal detection, software development, communications technology, large scale data management, and computer imaging.

One of the ways we are making these interconnections more obvious and more productive is by organizing research around strategic themes. These themes cut across traditional disciplines, making connections with national priority areas that bridge research fields and coordinate research within NSF and with other Federal agencies.

Our current budget request reflects a planning process that places increasing emphasis on research and education that is relevant to national priorities. It is worth noting that of the incremental funds we are requesting for the coming fiscal year, more than three quarters of that funding will go for research and education in the following strategic areas:

—Global Change Research
—High Performance Computing and Communication
—Advanced Manufacturing Technology
—Advanced Materials and Processing
—Environmental Research
—Biotechnology
—Civil Infrastructure Systems
—Science, Mathematics, Engineering and Technology Education

Emphasis in these areas reflects the President's priorities for investing in research and education that will allow the United States to maintain world leadership in science, mathematics, and engineering, while at the same time providing the basis for long-term economic growth that protects the environment. Of the $8 billion in the President's Science and Technology Investment package, NSF accounts for more than one third. The areas targeted for growth within NSF represent research fields that show promise for exciting near-term discoveries that also have near-term potential for application.

A more detailed discussion of our budget proposal is attached at the end of this statement.

HUMAN RESOURCES

I would like to spend a few minutes discussing the last item on the list of strategic priorities—the Science, Mathematics, Engineering and Technology Education activity. Within this area we expect to invest $650 million next year in a number of programs that will lead to improving the education of the coming generation. The majority of this funding will come from our Education and Human Resources Directorate, but a significant proportion comes from each of the other directorates as well.

This is because education, in a very real sense, is at the core of what we do at NSF. And in a rapidly changing world we must focus attention on education that prepares people for work in an increasingly technology-driven environment. We must educate students in ways that provide them with problem solving skills that will be useful throughout their lives, regardless of the changes that technology brings to the workplace.

The educational reforms supported by NSF and adopted in the various states have traditionally approached changes in small pieces—try out a new course curriculum, develop a teacher improvement program, experiment with a new technology, implement statewide testing, and so forth. We have determined that it is worthwhile to involve the states in developing bolder, more sweeping, and sustainable improvements in their educational systems.

To do so, we have formed partnerships with 25 states and Puerto Rico through our Statewide Systemic Initiatives to design and implement comprehensive changes in their teaching of math and science. Each of these will serve as an experiment both for the process of instituting systemic educational change and for developing science, mathematics, and technology programs that meet contemporary educational needs. NSF's systemic reform efforts are part of the Administration's commitment to help state reform our elementary and secondary educational system through Goals 2000.

NSF's role as the catalytic agent for change has been very successful in generating interest in systemic change. As a result, we have extended this approach with our Urban Systemic Initiatives—focusing on cities with large numbers of at-risk youth, and the Rural Systemic Initiatives, which addresses the special needs of economically disadvantaged rural regions.

We have also instituted an Advanced Technological Education program—thanks to legislation sponsored in this body by Senator Mikulski—to promote improvement in secondary school curricula and instruction to help in the transition from school to the high-performance workforce. This program recognizes that the highest quality science, mathematics, and technology education must be provided to students who plan careers that do not involve four-year colleges.

Finally, our Alliances for Minority Participation (AMP) program is making great strides in boosting the science, engineering and mathematics enrollment of underrepresented minorities. When we began the AMP program in 1991, underrepresented minorities accounted for about 14,000 BS degrees in science, engineering and mathematics annually. Our 15 AMP consortia, the oldest of which has been in operation just over two years, have already produced a net increase of 1,500 baccalaureate degrees to minorities.

I have spent a lot of my time on education because NSF takes very seriously our responsibility across the spectrum of mathematics, science, engineering, and technology education. We will not have a capable workforce in the future if we ignore this responsibility now. Nor will we have developed the talent required for the next generation of researchers unless we pay careful attention to the policies—implicit and explicit—that guide science, mathematics, engineering and technology education from kindergarten through post-doctoral work.

It is through higher education that many research innovations reach the business community. It has been said that one of the best technology transfer devices is the moving van that delivers freshly trained scientists and engineers to their first jobs. We are exploring ways to narrow the gap between the discovery process in universities and the implementation of discoveries in industry by providing incentives for greater industry-university collaboration.

ACADEMIC RESEARCH INFRASTRUCTURE

Let me conclude by briefly discussing a related issue, and that is the need to repair, renovate, and modernize academic research laboratories and instrumentation.

NSF currently provides little more than nominal assistance for infrastructure. To do more within our current budget would seriously skew NSF's highest priority—putting people first.

In September NSF's next report on the academic research infrastructure will be available to provide an up-do-date assessment of the needs. I have talked with Dr. John Gibbons, Director of the Office of Science and Technology Policy, about the need to consider academic infrastructure issues on a government-wide basis and I've recommended that this issue be reviewed by the National Science and Technology Council.

Revitalizing the academic research infrastructure requires the cooperation of all Federal agencies, as well as the support of the states, universities, and the private sector entities that fund academic research. NSF has been a leader in supporting merit-reviewed infrastructure modernization activities, and we will continue our efforts to upgrade facilities while we work to develop a more inclusive approach.

In conclusion, Mr. Chairman, I appreciate the opportunity to provide you with a summary of some of the important work being supported at NSF. We support the highest quality research and education activities and seek to connect work across strategic areas in order to make progress toward national goals.

I look forward to working with you and your committee to make NSF's contributions to the nation even more significant in the future than they have been in the past.

Thank you. I will be pleased to respond to any questions that you might have.

ACTIVITY SUMMARIES

Funding for the National Science Foundation is provided through the following seven appropriations.

RESEARCH AND RELATED ACTIVITIES

The FY 1995 Request for Research and Related Activities (R&RA) is $2,348.70 million, an increase of $185.0 million, or 8.6 percent, over the FY 1994 level [1] R&RA funds a broad range of activities focused on strengthening the nation's scientific, mathematics, and engineering research enterprise. Included is support for research projects, centers, instrumentation, user facilities necessary for forefront research, and education and training activities. Also included within R&RA is support for research in the arctic and antarctic regions, and the necessary logistics and operations support to enable such research.

Within R&RA, funding for research and education in strategic areas increases by more than 12 percent over the FY 1994 planned level. Efforts in these strategic areas produce the knowledge necessary to address a range of national priorities, to advance our understanding of scientific phenomena and technological processes, and to strengthen the science and technical workforce. Significant increments include:

---

[1] The Major Research Equipment (MRE) appropriation is proposed in FY 1995 to fund the construction of the Laser Interferometer Gravitational Wave Observatory (LIGO) and the Gemini 8-meter telescopes, currently funded through R&RA. for comparability, the FY 1993 and FY 1994 amounts for these construction projects are included under MRE.

—U.S. Global Change Research Program increases by more than $65 million, or 46.2 percent, for a total of $207.52 million. Special attention will be given in FY 1995 to major international data collection and analytic programs; to climate change modeling and forecasting activities; to research on terrestrial ecology; to research on policy processes; and to the advancement of methods for conducting integrated assessments.

—High Performance Computing and Communications initiative increases by more than $61 million, or 24.5 percent. This includes more than $50 million for Information Infrastructure Technology and Applications for information infrastructure services, system development, intelligent interfaces, and National Challenge Applications Problems in areas which have broad impact on the nation's competitiveness.

—Support for the interagency Science, Mathematics, Engineering and Technology Education initiative increases by more than $9 million, or 8.4 percent, to $118.53 million. R&RA-funded education programs are directed primarily at post-secondary education. Increased support in FY 1995 focuses primarily on improving undergraduate education.

Significant support is also provided within R&RA for efforts in strategic areas including Advanced Manufacturing Technology, Environmental Research, Advanced Materials and Processing, Civil Infrastructure Systems, and Biotechnology.

Funding for fundamental research in all disciplinary and cross-disciplinary fields of science and engineering supported by NSF will continue. Within R&RA, research project support increases by 10.7 percent to $1,404 million. Examples of projects supported include:

—Investigators funded by the Biological Sciences Activity have isolated a key gene controlling the intake of potassium and of toxic metals in plants. This research may lead to the development of genetically engineered plants capable of blocking toxic metals responsible for major agricultural losses from entering plants.

—Data from the 1993 floods in the Upper Mississippi Basin are being used by researchers funded through the Geosciences Activity to protect river systems against bank and levee sloughing and to determine the degree to which major floods recharge aquifers mined by irrigators and industries.

—Research in the formal methods for the design and analysis of fault-tolerant, real-time, distributed systems supported by the Computer and Information Science and Engineering Activity were applied in the national Air Traffic Control system in the form of the hand-off protocol used to transfer ownership from one air-traffic controller to another.

—The Nobel Prize in Physics for 1993 was awarded to NSF-grantees Joseph Taylor and Russell Hulse for their discovery of the first binary pulsar and for subsequent studies leading to high precision tests of Einstein's theory of gravitation.

—One of the greatest challenges for the chemist is the design of molecules and methodologies that mimic nature. Particularly exciting developments supported by NSF's Chemistry Subactivity are "chemzymes," small molecules with catalytic activities rivaling those of enzymes, and selfreplicating molecules designed at the Massachusetts Institute of Technology, taking lessons from DNA.

—Companies have used results from research on human cognition funded through the Social, Behavioral and Economic Sciences Activity, as it unfolds through language, memory, problem-solving, decision-making, and learning, to improve human/machine interfaces.

Funding for centers within R&PA increases by 4.6 percent for a total of $186 million. Activities include:

—When earthquakes occur, such as the recent Northridge, California earthquake, the NSF-supported Southern California Earthquake Center serves as a center to capture data, coordinate science activities, and provide public information.

—The NSF-supported Industry/University Cooperative Research Center for Measurement and Manufacturing Control at the University of Michigan developed a measurement methodology which allowed Chrysler's Jeep Grant Cherokee Plant to improve the dimensional tolerance of the assembly of automobile body panels to 2 mm, a tolerance standard used by Toyota Motors.

—Experiments at the Cedar Creek Long Term Ecological Research site in Minnesota demonstrated the importance of biodiversity on plant production following the major drought of 1988. Areas previously manipulated to contain high plant diversity maintained higher plant production during the drought and recovered more rapidly than less diverse areas.

—The NSF-supported Center for Ultrafast Optical Science has helped bring ten new products to market in its first three years, with sixteen others under development. The Center is now poised to launch the Ultrafast Development Laboratory where scientists and engineers from private companies will conduct experiments related to product development along with Center students.

Support for facilities within R&PA increases by 6.0 percent to a total of $559 million. Activities have included:

—More than 1,200 U.S. colleges and universities are fully connected to the Internet, with traffic carried by the NSFNET Backbone Service in December 1993 almost double that carried a year before.

—The four NSF-supported Supercomputer Centers continue to provide over 8,000 users with access to state-of-the-art computing resources not available elsewhere. Their Centers' scope has expanded to include partnerships permitting private sector organizations to experiment with the application of high-performance computing technologies.

—Since its creation in 1960, about 30,000 people from 250 institutions across the country and around the world have visited the National Center for Atmospheric Research and used its facilities, including aircraft, supercomputers, and ground-based observing facilities.

—NSF funding for the three major national facilities in astronomy supports operations, maintenance, and development of instrumentation in groundbased optical and radio astronomy.

—Facilities supported through the U.S. Polar Programs enable research in the Antarctic by providing the necessary infrastructure for scientists, including aircraft, research vessels, research stations, and logistical and operations support.

Funding for education and training activities within R&RA increases by 5.2 percent to a total of $199 million. Efforts include support to provide research experience for undergraduate students, reform undergraduate curriculum, explore innovative educational delivery systems, experiment with innovative applications of technology for educational activities, increase the involvement of women and underrepresented minorities through special programs and mentorship activities, provide doctoral dissertation support in research areas requiring field work, and allow faculty at small colleges to update their skills.

Highlights of R&RA by Activity are:

—The Biological Sciences (BIO) Activity promotes understanding of the underlying principles and mechanisms governing living organisms. Research areas include analyses of the genetic and molecular processes underlying all life; the use of cutting-edge tools to understand organism development and behavior; modeling of the interrelationships among organisms and the environment in which they live; and the development of new instruments and databases for the biological sciences. The 9.1 percent increase in FY 1995 will primarily support research in the U.S. Global Change Research Program and High Performance Computing and Communications, allowing enhanced support for research on biodiversity and the environment, Long Term Ecological Research sites, and the establishment of a Center for Ecological Analysis and Synthesis.

—Research in the Computer and Information Science and Engineering (CISE) Activity is directed at information processing in the broadest sense, ranging from fundamental theory of computing to systems architecture and engineering. In addition, significant attention is devoted to advanced computer and communications facilities providing services for the general research and education community. The 13.7 percent increase in FY 1995, directed toward the High Performance Computing and Communications initiative, enhances support for its Information Infrastructure Technology and Applications component, increases high performance computing capabilities at NSF Supercomputer Centers, and provides for a transition to very high-speed networking.

—The Engineering (ENG) Activity promotes the progress of engineering and increases its potential to respond to the nation's future technological opportunities and needs. ENG accomplishes its mission by supporting all fields of engineering education and research and by developing the nation's engineering human resources and physical infrastructure. Engineering's 9.7 percent increase for FY 1995 will go to support increases in Advanced Manufacturing Technology and High Performance Computing and Communications, and to meet mandated levels for the Small Business Innovation Research (SBIR) program.

—The Geosciences (GEO) Activity supports research to advance knowledge of the properties and dynamics of the planet Earth including: studies of geologic forces and their history; ocean dynamics and resources; and the physics and chemistry of the atmosphere. The 9.7 percent increase in FY 1995 reflects emphasis on the U.S. Global Change Research Program and will enable new and enhanced efforts in international data projects, forecasting and climate modeling, terrestrial ecology, and integrated assessments.

—The Mathematical and Physical Sciences (MPS) Activity supports research in mathematics, astronomy, physics, chemistry, and materials science to accelerate the growth of the knowledge base and to connect it to potential users. Major equipment and instrumentation such as accelerators and telescopes are provided to support the research needs of individual investigators. The 6.3 percent increase in FY 1995 will strengthen support and boost MPS participation in all interagency and NSF research initiatives and enhance support for facilities and instrumentation.

—The Social, Behavioral and Economic Sciences (SBE) Activity stimulates scientific progress in the social, behavioral and economic sciences. Research focuses on how various social and economic systems are organized and operate and how cognitive and cultural factors influence human behavior. The Activity also includes programs that promote international scientific cooperation and provide authoritative data on science and engineering and the characteristics of the nation's research and education enterprise. The 14.6 percent increment in FY 1995 will primarily support the U.S. Global Change Research Program.

—Polar Programs, which includes the U.S. Polar Research Programs and U.S. Antarctic Logistical Support Activities, support multi-disciplinary research in arctic and antarctic regions. Polar regions play a critical role in world weather and climate and provide unique research opportunities from the ocean bottom through the ice layer and into space. Special logistical and operations efforts are required to support research in Antarctica because of its remote location and the necessity of providing all infrastructure. The 2.1 percent increase in Polar Programs will be directed entirely to research projects rather than logistics. This represents an 8.8 percent increase in research and will enable expanded studies in arctic and antarctic regions, focused primarily on global change and environmental issues.

—The Critical Technologies Institute is a Federally-Funded Research and Development Center that provides analytical support to the Office of Science and Technology Policy by identifying near-term and long-term objectives for research and development; analyzing the production capability and economic viability of technologies; and providing options for achieving R&D objectives.

EDUCATION AND HUMAN RESOURCES

The FY 1995 Request for Education and Human Resources (EHR) is $586.00 million, an increase of $16.40 million, or 2.9 percent, over the FY 1994 Current Plan. EHR supports a cohesive and comprehensive set of activities, augmented by informal science experiences, which encompass every level of education and every region of the country. EHR plays a major role in science, mathematics, engineering and technology education, funding about thirty percent of the total federal effort in FY 1995.

—Support at the K-12 level totals $360.05 million, an increase of $8.87 million over FY 1994. Included in this amount are Systemic Reform activities ($86.06 million) in states, urban and rural areas, and programs to meet the National Education Goals in science and mathematics, established in 1990 by the President and the nation's governors.

—Support at the Undergraduate level is $102.25 million, an increase of $2.44 million over FY 1994. This support focuses on the continued efforts of reforming curriculum and laboratory instruction, and upgrading equipment. Improving undergraduate preparation of K-12 teachers and addressing advanced technician training continues to be major emphases.

—Support at the Graduate level is $63.39 million, an increase of $4.60 million over FY 1994. Included in this support is a modest increase in both the stipend and the cost of education allowance for the Graduate Fellowship program. The number of fellows will be sustained at approximately 2,400. The Graduate Traineeship program will be sustained at the FY 1994 level.

—Advanced Technology Education (ATE) established in FY 1994, is $17.60 million, an increase of $3.00 million over the FY 1994 level. ATE promotes improvement in advanced technological education curricula and instruction to help in the transition of students to the high-performance workforce. The increase will support new centers and expansion of curriculum projects.

ACADEMIC RESEARCH INFRASTRUCTURE

The FY 1995 Request for Academic Research Infrastructure is $55.0 million, a decrease of $50.0 million from the FY 1994 Current Plan level of $105.0 million, but the same level requested in FY 1994. Because academic infrastructure needs are so pervasive, only with the concerted cooperative effort of every agency that funds academic research, and with the support of the Congress, can the federal government begin to address the large scale modernization and instrumentation requirements of our science laboratories and classrooms. The $55.0 million Request is the amount NSF feels is sufficient to allow the continued upgrading and improvement of research facilities and instrumentation at academic institutions, while maintaining the Foundation's traditional role in the research community.

MAJOR RESEARCH EQUIPMENT

The FY 1995 Request for the new Major Research Equipment (MRE) appropriation is $70.0 million. MRE is established in FY 1995 to provide funding for the construction of major research facilities that provide unique capabilities at the cutting edge of science and engineering. Currently funded through the Research and Related Activities (R&RA) appropriation, these construction projects totaled $34.07 million in FY 1993 and $52.00 million in the FY 1994 Current Plan. The FY 1995 Request of $70.00 million represents an $18.00 million increase, or 34.6 percent, over the FY 1994 level for these items.

Projects supported by this Account will push the boundaries of technological design and will offer significant expansion of opportunities, frequently in totally new directions, for the science and engineering community.

Two projects currently comprise the Major Research Equipment Account: the Laser Interferometer Gravitational Wave observatory (LIGO) and the Gemini Telescopes, twin 8-meter telescopes in the northern and southern hemispheres being built through an international partnership.

SALARIES AND EXPENSES

The FY 1995 Request for Salaries and Expenses (S&E) is $130.72 million, an increase of $12.42 million, or 10.5 percent, over the FY 1994 Current Plan level of $118.30 million. The Request level fully funds the Foundation's staffing requirement of 1,243 full-time equivalents and will enable NSF to exercise effective management of its programs and activities and to continue its investment in advanced information technology.

Salaries and Expenses provides funds for staff salaries and benefits, and general operating expenses necessary to manage and administer the NSF. Funds are requested separately for the Office of Inspector General and for NSF Headquarters Relocation, the appropriation account which includes funds to reimburse the General Services Administration (GSA) for expenses incurred to relocate the Foundation to its new Headquarters location in Arlington, Virginia.

NSF HEADQUARTERS RELOCATION

The FY 1995 Request for NSF Headquarters Relocation is $5.20 million, equal to the FY 1994 level. This appropriation account provides annual reimbursement to the General Services Administration (GSA) through FY 1998 for expenses incurred by GSA pursuant to the relocation of the National Science Headquarters to Arlington, Virginia, which was completed in January 1994.

OFFICE OF INSPECTOR GENERAL

The Office of Inspector General (OIG) was established to promote economy, efficiency, and effectiveness in administering the Foundation's programs; to detect and prevent fraud, waste, or abuse within NSF or by individuals that request or receive NSF funding; and to identify and resolve cases of misconducting science. The FY 1995 Request for the OIG is $4.38 million, an increase of $0.38 million over the FY 1994 level.

The CHAIRMAN. Thank you very much.

With regard to women and minorities in science, factually, that program goes back to 1977 and 1978 legislation, we are impressed by some of the more recent activities. I do not think we kept after the agency as much during that period of time, quite frankly, as we should have. We had the Women in Science and Technology Equal Opportunities Act in 1977 and 1978, and in 1979 as well, which the NSF was to respond to. So we are enormously interested in continuing to watch and encourage that kind of enterprise.

You mentioned the importance of science research and education in strategic areas, and you pointed out that more than three-quarters of the growth of the NSF budget is allocated to research and education strategic areas. How do you arrive at that number? How does the focus on research in strategic areas relate to the NSF longstanding mission on initiating and supporting basic scientific research?

Mr. LANE. Mr. Chairman, the strategic areas are broad areas of science and engineering that support particular national goals such as protecting the environment, making industry more competitive, and getting information to the fingertips of all Americans. These are very broad goals that go far beyond the science and engineering necessary to go forward. But all of them do have an underpinning of science and engineering that is needed. So that in these strategic areas, we identify particular areas of science and engineering, including environmental research, global change, biotechnology, the others that I mentioned in my testimony.

NSF emphasizes basic research, that is, research aimed at discovery of new knowledge and the nature of the works of humankind. Thus, the support of basic research in these broad strategic areas is fully consistent with the mission of the National Science Foundation.

It is also important to have a balance between that research that we think might lead in the near term to knowledge that will help us to advance one or another of these important goals, balance that with research, where we really do not know what might be the short-term payoff, because we do know from history that you cannot really predict. So long as one supports a healthy program, good things will come out of it. Therefore it is a balance issue.

Our priorities at the present time, the administration's priorities, are to invest more in that basic research that does underpin these strategic goals. So of the funds we are requesting for 1995, about $180 million will go for research that can be directly identified with one or another of these strategic goals. As a fraction of the something over $200-$220 million of money requested to go into research and related account, that amounts to over three-quarters, probably closer to 80 percent than to 75 percent.

The CHAIRMAN. Once you set these areas, because they are basically rather global in nature, how then do you decide where you are going to move? I mean, these are broad areas of very important public policy questions which the NSF has a unique ability to try to deal with. But once you get the broad area, how do you then decide as to what is going to be the sub-area where you are going to focus resources?

Mr. LANE. Mr. Chairman, some of the areas sort of speak for themselves. In the area of high-performance computing and communication, for example, almost all the work we do in the science and engineering that advances our understanding of information, information technology, networking, and visualization, is clearly identified with the goal of building a national information infrastructure. But just to keep us all honest, there is a strong, interagency, coordinated activity, started under the FCCSET process and being continued under the President's new National Science and Technology Council. There is a structure of committees that support that council that work on a weekly basis, sometimes more frequently, on the detailed planning of the research engineering and mathematics activities that are necessary to advance understanding of these areas. So the detail is worked out with a number of agencies sitting down together and bringing to the table what each agency can do in order to help the larger program move forward.

The CHAIRMAN. Finally, how do you evaluate research to see what has been useful? I mean, there will be some projects for which the results will be obvious in terms of where they lead, and others whose applications may not be as obvious, but in the longer term, may be as important. How do you ensure that research being done is consistent with the broad areas that you have outlined here as being in the national interest?

Mr. LANE. Mr. Chairman, one of the things that is true about basic research is that you really ought to reach out; you ought to take some chances; you ought to try to do some things that maybe you cannot be confident you can do. And so from time to time, a perfectly capable researcher with a great idea is not going to produce a discovery. And in fact, we do not expect that we can predict when a discovery is going to be made or when we are halfway there, or even if a discovery is going to be made on a project-by-project basis. But if you look across a whole program with lots of projects and lots of investigators trying different things, you ought to be able to identify measures that tell you whether you are doing a good job.

We have long had in place a system of merit review at the National Science Foundation which remains one of the core values of what we do and how we do business. That merit review includes peer evaluation, but it is more than that. It is the judgment of scientists, engineers, and mathematicians who work at the National Science Foundation and who ensure that the projects that are funded in fact merit that funding.

So project by project, we do review very carefully what gets done, but the point I want to emphasize is that if it is basic research, then for a particular project, you have to be ready for failure occasionally. For a broad program, I think it is appropriate for us to ask ourselves harder questions and be asked harder questions about how do we measure what goes on across a program. In some areas, it makes sense to have milestones. If you are building a major facility, then you have to have a management plan, and you have to know how much of the facility you are going to have built after the end of the third month and the sixth month and how the money is going to be expended. And we have always done that, but we have not made it as explicit as we might.

In other areas where we are expecting the results of many, many research efforts to move us forward in understanding global climate change or various aspects of environmental research, then we need to also be able to lay down measures and sometimes milestones. Sometimes they can be quantifiable. Suppose we plan to get curriculum materials in the hands of teachers, or we plan to impact a certain number of students with our education program; those are things we can really appropriately set goals to do, and those have quantitative aspects to them. So we should expect to measure over time what kind of progress we make.

In general, for all of the strategic areas that I have described, we are going to identify as a part of our planning process that is going on right now, measures that will help us respond to questions about how do we know that the research that we are supporting is really advancing our understanding of one or another area. And we expect by this summer, Mr. Chairman, to have made considerable progress in that.

The CHAIRMAN. Thank you.

Senator Mikulski.

Senator MIKULSKI. I am happy to yield to Senator Gregg.

The CHAIRMAN. We are co-chairing this morning, Judd, so I was caught as to whom we should recognize first.

Senator MIKULSKI. Co-chairing, but not co-equal in this area. [Laughter.]

Dr. Lane, we want to welcome you to this hearing. Senator Kennedy, Senator Gregg, just a few days ago, we held the appropriations hearing on the NSF budget, and I think this is really what a new era needs to be, where the authorizers and appropriators are working together.

Dr. Lane, I want to talk about an authorizing framework to incorporate the concept of strategic research along with making sure that NSF has the flexibility and nimbleness to adapt to new times. As everyone in the room knows, I am the author of an appropriations committee report saying that NSF had to do 60 percent in strategic research. That created a firestorm, because everybody thought I mean applied research or project-based research, rather than the NIH model where you have a variety of types of research working toward a national goal.

I speculated, in reauthorizing the Foundation, on suggesting that NSF be reorganized the way NIH is, on strategic goals, instead of the way you are currently organized. For example, it would be the directorate on global climate, or directorates along similar strategic themes. What would be your commentary on that? I am interested because I seek an outcome, and an outcome where a substantial part—not all—of the National Science Foundation budget goes to achieving national goals. I also do not want to hamstring the structure of NSF or America's scientific community. What would you think about the reorganization of NSF along the lines of NIH?

Mr. LANE. Madam Chair, we certainly are looking at the organization of NSF. The organization, as I commented in my testimony, has evolved over the years, and as a part of the strategic program planning process that is underway right now, certainly, organization is one of the things that we will look at.

My expectation is that out of that planning process there is likely to come a more multidimensional matrix organization scheme, with strong vertical and horizontal lines. We have some experience with this approach, but I think it is probably not so visible outside the agency, because as we have worked to coordinate activities that run across the disciplines, we have had to put in place in the organization a mechanism for doing that. But that is something we will look very hard at. I am certainly open to what comes out of the planning process. But there are a couple things to keep in mind, if I might just comment quickly on those.

It is important that we not have to change the organization too often. It is also important that we not add a bureaucracy or extra staff work. Indeed, we hope we can look for ways to streamline our organization, which would be consistent with the National Performance Review. And whatever organization is used, what is absolutely critical is that the organization allow the most rigorous evaluation of the merits of the proposal against well-established standards of excellence. That really is at the heart of what has made the NSF contributions so important to the Nation, and that is something we must continue to maintain and improve, if we can.

So the question is how best to organize the NSF so that it is more efficient, effective, and responsive to the Nation's needs. And the planning process is certainly going to address this question.

Senator MIKULSKI. I acknowledge all of that, but here is where we are. We have to move an authorization. There might be a gap in the timing of the reauthorization and your planning process. What I am asking for, and I think the Chair and others on the committee are also looking for, is your recommendations as to: number one, how to operationalize these good intentions, and number two, how to institutionalize them in a way that begins to change the culture of the way NSF has operated in its relationship with universities and at the same time, provides flexibility and look forward to the future, leaving lots of room for the unanticipated, the undiscovered, in a way that will require continual refocusing.

So that is why I asked about the NIH model, and we are going to need to know pretty quickly what your thoughts are on that.

Mr. LANE. Madam Chair, I appreciate the importance of the question, and certainly take it seriously. I certainly agree that nature has no boundaries, but nature is organized, and the disciplines that have evolved—chemistry, physics, mathematics—have evolved around the organization of nature and the way people think and so on. There is a rationale for that. So the question again is how to be sure that we are able to evaluate what we do well and ensure that we are advancing knowledge along all of those frontiers, while at the same time, cutting across these disciplines to address the strategic initiatives that we want to do.

Senator MIKULSKI. That is what I am asking for. When is your planning process going to be done?

Mr. LANE. We would anticipate discussion with the board this summer, and I have asked the planning committee for a report in all of these areas by May 1.

Senator MIKULSKI. By May 1.

Mr. LANE. Yes, Madam Chair.

Senator MIKULSKI. I think all of us on the committee would want to discuss with you what the structure of the National Science Foundation should be as we move forward on the reauthorization, whether it should be changed and a variety of these things. I do not want to keep repeating myself, but this train is going to leave, and either we do it together with your recommendations, or I am sure there will be sharply differing views even on the committee on how to proceed.

I would look for a consensus between the committee and the Foundation.

Mr. LANE. Well, Madam Chair, the report will come to me in May, and then we will be discussing with the board in the summer. Would a response to you in July be early enough?

Senator MIKULSKI. What do you think, Senator?

The CHAIRMAN. Why don't you go back and talk with your people and see what your best time would be? Clearly, I think we want to talk with the leadership about the scheduling. We will be getting into a very tight time bind.

Senator MIKULSKI. You see, the appropriations begin, and health insurance could possibly be on the floor. We do not want to delay the reauthorization. We want the Foundation to have a very clear navigational chart with its reauthorization. And I do not think that the reauthorization has to dot every "i" and give you a rigid blueprint. We do not want rigidity. But I do think there has to be a quicker step and a quicker pacing.

Mr. LANE. Well, Madam Chair, Mr. Chairman, we will certainly go back and discuss this, and we want to work with you as we move toward this reauthorization, which is very important to us.

The CHAIRMAN. Could I just add that we are not interested in rearranging deck chairs on this. For example, on mental health, we made the judgment that with the research that was taking place in that area, it was better for the institute to be out there at NIH rather than where it had been previously.

For example, OTA maintains a capacity in terms of health and the health sciences. They do not have a directorate, but they maintain a professional group, while they have evolving and changing areas of interest as the Congress begins to move into health care reform.

So we are trying to work with you and think about different kinds of organizations. I think what we are asking for is a hard look by yourself and those who have been involved and have had long and distinguished interests. If NSF's organization should stay the way it is, then we need good reasons why it should. If it is going to change along problem-oriented lines, then how does this really serve the national interest? Should there be change, or should NSF make some changes now and do some evaluations, or pursue some other strategy? I do not think we are trying to make life more complicated; we want to work with you, and we will do some follow-up with you.

Senator MIKULSKI. May I just ask one other question related to education?

The CHAIRMAN. Yes.

Senator MIKULSKI. We talk so much about education, and I believe that Dr. Luther Williams, and the continuity between Massey-Lane, have done an excellent job in things like the urban initiative. But I happen to believe that not all education goes on in schools, and some of the best education occurs outside of schools, particularly in science and math, where hands-on is important.

Could you share with us, as we reauthorize NSF, how we can be sure to incorporate the ability of the National Science Foundation to work with alternative forms of education—and what do I mean by that? Science centers, and not only the wonderful ones like in Baltimore, but small science centers in rural areas where not only kids, but teachers go to be retrained and retooled on both science itself and the new techniques; and then also, the people who teach science.

I happen to think Scouts teach science by working on projects in earth science and the environment, both Boy Scouts and Girls

Scouts, boys' clubs and girls clubs'. This is where those 9-year-olds get their hands into it, and they do not even realize they are doing science, but they get involved in it. This is then the incubator for them to pay attention in school in these topics and then even go into fields ranging from lab technician to nurse practitioner to M.D. to physicist to Ph.D.

I wonder what your thoughts are on incorporating these ideas in reauthorization, or should we just leave that the way it is because it gives you maximum flexibility to do these things?

Mr. LANE. Madam Chair, I think we do have flexibility to do that. We do support some programs in science museums and television outreach activities and other ways of trying to get to young people and not so young people as well, because we agree with you. Some of the most exciting times that I spent through my years as a young person and more recently have been in science museums, many around the country, including the one in Baltimore. I have had a good time, and it is hard to get me out of those. And I think what has really happened through the years is what you refer to, that by moving in a direction that allows the visitor to the museum to get hands on, it captures the imagination, so the romance of science, that easily gets lost, gets recaptured in that kind of environment. It has been a marvelous evolution. I am very interested in that particular area and would be pleased to work with you on some further ideas. I appreciate the question.

Senator MIKULSKI. Well, thank you.

The CHAIRMAN. Senator, would you yield to me just for one observation on this—we are trying to balance the time——

Senator MIKULSKI. I am finished—I have a million questions, but I am done.

The CHAIRMAN [continuing]. My son did a science project at school involving seeds. They watered the seeds with melted snow, tap water, and then bottled water, to see the impact of acid rain, which we have here and we get a lot in New England. They did it for 7 weeks, and the dramatic change in using tap water, melted snow and bottled water on the growth of these seeds was just mind-boggling. And that child is absolutely fascinated—now, I do not know how long that interest is going to last——

Senator MIKULSKI. So are you. That is what is so great about it.

The CHAIRMAN. Yes, I am, too. [Laughter.] Then, they asked the science class to use a mousetrap to send their own little built cars across the room, to see who could be the most ingenious about it. But there are 500 kids in there, and it is just absolutely dramatic in terms of how the kids are interacting.

And finally, I would just note Ballard, with his program in the underwater seas, where he has found the Titanic, the Lusitania and the Bismarck. He was in the Galapagos Islands and was tied into the Boston school system. I went to the Museum of Science up there. They had 1,200 inner-city kids, and you could have heard a pin drop. I mean, normally, you would try to have quietness in the room with 10 kids or any kids,, and it would be difficult. They had read about wooden boats that had sunk in the Great Lakes and in Lake Champlain, and why wood deteriorates or does not, and how wood that comes up into the air collapses, and so on.

So just in a creative and imaginative way—we know what you have to do and how it can be done—but I think as a society and as a country, in many respects, we are dead in the water in terms of trying to keep this kind of inquisitiveness alive. So to the extent that we can be sensitive, returning curiosity and excitement would be something that I think parents and many of us would be very interested in.

Mr. LANE. Mr. Chairman, if I could just quickly comment on that, we have marvelous organizations, science museums and other organization, all around the country. I mean, the resources are really there, and with the putting in place of the national information infrastructure, I think there is an opportunity to connect all of these great minds and ideas and visualizations and demonstrations, and get them into the classrooms and into the homes, where the young people can see them and share that excitement.

But in the end, there is no substitute for being there where this is really going on, and talking to the person who has had this kind of great adventure and can share that kind of electric feeling about what it is to explore, what it really is to do science. That is what science is all about. But what we have not done a good job at through recent decades, including the time I was educated, is saying that science is really what is in textbooks, and it is dry, and it turns a lot of kids off. So we are making some progress there, and this is an area that we are very interested in.

The CHAIRMAN. Thank you.

Senator Gregg.

Senator GREGG. If I can pick up on this, because it is something I have been interested in for a long time—and I echo what the chairman has said and what Senator Mikulski has said—a long time ago, you folks funded things like "Voyage of the Meemie," which was a program on public television that was "hands-on" through TV, helping kids learning about the ocean, and you funded "3-2-1-Contact." I recognize that this type of activity is considered beneath pure science, and that there has always been a conflict within the National Science Foundation over the desire to do pure science and the desire to be in the marketplace of promoting science amongst students. But I just want to echo the words of the chairman in saying that I think you obviously have been committed to that, and I just want to congratulate you and encourage you to continue to expand that effort. And working with national public television and other groups like that, I hope that the National Science Foundation will continue to do a lot of outreach toward elementary-level students.

In that context, I know that you have this systematic reform program going forward, and I guess there are about 25 States participating in it. I had a chance in my former job to make an application and was involved; in fact, I met with the people that you sent to New Hampshire to review the proposals. I guess my reaction at that time was that it seemed awfully bureaucratic, not only in the way in which the reviews were occurring, but also in the type of proposals which were being sought. There seemed to be an emphasis on proposals which were put together by professional fund writers and grants men, and the creation of a new level of grants men and promoters within different States, of consultant groups within States to promote science education.

I am only speaking uniquely from New Hampshire's experience in trying to get a grant. We did not get a grant, and I am not sure if our proposal was strong enough compared to the other proposals. I thought it was a reasonable proposal, but I was concerned that much of the proposal had to be shifted out of what I thought was important in the hands-on element of primary and elementary and secondary education in math and science to whether you call it systemic, and it was systematic, I suppose—what really was another level of bureaucratic oversight.

I am just wondering whether you sensed that sort of conflict at all from these systematic attempts. I think it is an important initiative; let me say that. I think it is critical that the National Science Foundation plays a major role in math/science education. I think it is a lot more credible for a teacher to have interfaced with the National Science Foundation than with the local education department. It gives that teacher the feeling that he or she has been sitting with the best and the brightest, and it is a better addition to their credentials to have a National Science Foundation workshop rather than State department of education workshop, so I think it is critical that you remain involved and that you be active.

I am just wondering what your analysis is of your systematic effort here.

Mr. LANE. Senator, I really do appreciate your comments. First, your comment on the traditional conflict within National Science Foundation which might, I think, reflect the conflict in the wider community between the kinds of things we were talking about a little earlier and basic science—let me officially declare the conflict over here and now——

Senator GREGG. Great.

Mr. LANE [continuing]. Because I think it really is over. My time here in the NSF has shown me that across the Foundation, staff care deeply about these issues we have been talking about here most recently. But I also find as I go out into the community—to science conferences, departmental colloquia, where I am really talking with researchers—the concern about public understanding of science/mathematics education is very real. Lots of folks do not know what to do about it, but the concern is very real. So I would emphasize the appreciation of what I said earlier, or should have said if I did not, that these activities really are at the core of what the NSF is doing, and that we are in that for the long haul.

Senator GREGG. It is easier for us, too, because we can understand that—we can understanding putting seeds in a glass; we cannot understand basic research.

Mr. LANE. OK. I would like to talk about that, too, but not right here at this point, I think.

I think that what we are trying to do with systemic reform is very difficult because what has really evolved in NSF's support of educational programs through the years was that back in the early days, when I was here earlier, we supported individual projects primarily in universities, and the focus really was on undergraduate and graduate education. Then we evolved to take more interest in

K-12, to be more active in K through 12 education, but still funding primarily through universities. We realized—and I take no credit for that, because I was gone all through those years—but the NSF realized that the way to really make a difference is through systemic reform, and that means you have got to change the whole system; you have got to pull all the players together—the State, the industry, the city, and in many cases, the universities and the school system, have all got to work together.

Well, there is a lot of bureaucracy in that system already, and in order to bring those partners together as partners, it is a more complex approach, I would say, to trying to advance education in this country than we might have used in the past. So I am sensitive to your point, Senator, and it is something that I am anxious to learn a good bit more about and see if there is something about the way we proceed that can make it more efficient and effective in getting the best proposals. But my sense is our proposals are carefully reviewed, and progress is carefully reviewed, and if things do not work, we shut them off.

Senator GREGG. I think you are making significant progress in this area. I wish New Hampshire had been able to participate. I might suggest that a peer group for review might be first and 2nd grade and 4th grade teachers who are not science-dependent. Have them take a look at what you have developed and ask them whether or not that has impacted their classroom, or would, in its different State. And I think you will find that some folks will say, "I am never going to hear from that level of bureaucracy you have set up."

From my view, that is where we have to start, in the 4th, 5th, 6th grade, especially with girls, to capture them in science and then aggressively keep them involved when they hit the seventh and eighth grade, where girls are falling out of the system.

A separate issue is the indirect cost pause. Doesn't that end up penalizing university systems or researchers within universities who are on an upward trend, doing things that are aggressive and pushing the envelope and expanding? Doesn't that group inevitably end up being the ones who are most significantly and detrimentally retarded by this pause, versus the folks who have just sort of settled into a standard of research which may not be as expansive or as exciting—"exciting" may be the wrong word—but are not in a dramatic growth period because they are developing more ideas and initiatives?

Mr. LANE. Well, Senator, I do not have the benefit of a detailed analysis on it, but I know that just anecdotally, quite a spectrum of institutions would project additional research money coming in next year and additional indirect costs recovered. So including major research universities, I know from responses that I have heard to the proposed pause that many of the major research universities in the country feel that they will also see significant cuts as a result of the pause. They have been long established, but they have also been increasing their research activity every year for a number of recent years, and are projecting that next year.

Senator GREGG. I guess my point is that I see the indirect cost pause as an arbitrary decision. Wouldn't it be more thoughtful of us as authorizers and Ms. Mikulski as an appropriator to give you the dollars less the pause dollars—in other words, to give you a number that assumes a pause—but allow you to distribute it throughout the research community without a pause as a function of the distribution? That way, if you have a program where indirect costs are going to go up because of the fact that they are doing something exciting, but to do that exciting thing, they have got to have their overhead covered, you can undertake that. Then you have to take it away from some other program, but you will have the flexibility to move the dollars around within the lower or the lesser figure.

Mr. LANE. Well, Senator, of course, the pause is an administrative decision, and I will support the administration's position here, and NSF will do what it can to help the universities respond, will help them establish their base and do whatever is necessary. It is a complex matter, as is overhead in general.

What I would say in general about the overhead issue is that it would be good—and I think the administration is committed to this—to move toward a system of overhead recovery that is less complex, and my understanding is the administration is anxious to continue to discuss with universities how that might be accomplished.

Senator GREGG. Well, as I understand the administration on the pause issue, it is just a dollar function. It is an OMB decision. They want to save some money, so they use the pause. So why not give you the flexibility? We will save the money, but we will give you the flexibility to spend it. I would think that would be a more logical way to approach it. But I can understand OMB being more of a "bean counter" approach and not wanting to do that.

The CHAIRMAN. Senator, we have another panel to hear from, and it looks like we will probably have to terminate the hearing at 11:30. Obviously, if you have another question, we welcome it, but we want to try to give our final panel an opportunity as well.

Senator GREGG. Well, I do not want to hold up the other panel, but I do have two other questions I would like to ask Dr. Lane that, hopefully, he can give me a quick answer to, and they are reasonably related.

On the issue of commercialization, from basic research to commercialization, do you have any suggestions as to what we should be doing to be more aggressive? Obviously, we have done some things, but do you have any suggestions as to what else we could do?

Second, on the issue of the Internet and the information highway, can you give us a thumbnail statement of what you think our role should be in expanding Federal involvement in that?

Mr. LANE. Well, Senator, I think I can start backwards on the information highway. The National Science Foundation, of course, has played a key role in getting the information infrastructure in place. The primary reason for that was because it was an important part of the research infrastructure, and we needed to do that so that our researchers could access high-performance computing and one another, and I would say that it has been a tremendous success.

As we move toward a full national information infrastructure that at some stage will become a utility, I think NSF's role will be, as it always has been, to engage in research activities that will advance our understanding of the technologies that are necessary to continue to upgrade those kinds of services. So in the long-term, that is what I would see as NSF's position.

On additional ways to get our ideas into the market, as a part of the planning process I described, we will be looking at what the appropriate levels and nature of the interaction between universities and industry is; are there places where we really are missing opportunities, where industry really wants more interaction with universities, but for some reason, there are barriers there, and vice versa. I think it is a very important area, and my sense is there probably is more that can be done, but I do not have anything more detailed to share with you at this moment.

Senator GREGG. Thank you.

Mr. LANE. Thank you, Senator.

The CHAIRMAN. Thank you very much, Dr. Lane. We appreciate your presence here and your responses.

Mr. LANE. Thank you, Mr. Chairman. Thank you, Madam Chair.

Senator MIKULSKI. Thank you.

The CHAIRMAN. Our next panel includes Dr. Roland Schmitt, who brings a great breadth of experience to our discussion this morning. Dr. Schmitt received his doctorate in physics from Rice. He has served as president of a major research university, Rensselaer Polytech, and he has been vice president of a major industrial corporation, General Electric. He served as chair of the National Science Board and the Industrial Research Institute and has been a member of the executive committee of the Council on Competitiveness. He is a member of the National Academy of Engineering.

Dr. John Bush is vice president of corporate research and development at The Gillette Company. Gillette is headquartered in Boston, but they also have a research laboratory in Gaithersburg, MD. Since Dr. Bush is here to discuss the role of NSF-funded research and trained personnel in developing commercial products, it is good to know that scientists from both my State and Senator Mikulski's were involved in the process. Dr. Bush holds a Ph.D. in chemistry from the University of California-Berkeley, and holds a number of patents in addition to his other contributions.

Dr. Kerry Davidson comes to us from Louisiana, where he is senior deputy commissioner for academic affairs and sponsored programs at the Louisiana Board of Regents. Dr. Davidson holds a doctorate in modern European and American history from Tulane. Fortunately for Louisiana, he decided to make a career of improving science and math education. He is project director of the Louisiana Systemic Initiatives Program and of the NSF Collaborative for Excellence in Teacher Preparation. In addition, he has worked closely with the Rural Systemic Initiative Project in the Mississippi Delta and an Urban Systemic Initiative Project in New Orleans.

We welcome all of you. We will include all of your statements in full for the record, and we would ask if you would be good enough to try to make your presentation in a timely way, as close to 5 minutes as you can, so we can ask some questions.

Dr. Schmitt.

STATEMENTS OF ROLAND W. SCHMITT, PRESIDENT EMERITUS, RENSSELAER POLYTECHNIC INSTITUTE, AND SENIOR VICE PRESIDENT, RETIRED, SCIENCE AND TECHNOLOGY, GENERAL ELECTRIC; JOHN B. BUSH, JR., VICE PRESIDENT, CORPORATE RESEARCH AND DEVELOPMENT, THE GILLETTE COMPANY; AND KERRY DAVIDSON, SENIOR DEPUTY COMMISSIONER FOR ACADEMIC AFFAIRS AND SPONSORED PROGRAMS, LOUISIANA BOARD OF REGENTS

Mr. SCHMITT. Thank you, Mr. Chairman. I will abbreviate the submitted oral testimony that I have given to you.

The CHAIRMAN. Thank you.

Mr. SCHMITT. I appreciate this opportunity to testify on the reauthorization of the National Science Foundation. Although I am a member of the National Science Board, I am not speaking in that capacity today. I am speaking at the invitation of the committee on the views I have expressed recently in published articles.

The role of the National Science Foundation in pursuing national goals is a subject of considerable discussion today. It is usually characterized by saying that the scientific community believes that NSF's traditional role of supporting investigator-initiated basic research should be preserved above all else while the political community and much of the public believe that it should devote most of its effort to addressing national goals.

My position is very simple: There is no fundamental conflict between these goals. Along with my oral testimony, I would like to submit two papers and talks that I have given recently on this issue, talks and papers I have given to the scientific audience, pointing out to them the truth of what I have just said.

This morning, I want to address some of the political concerns and suggest that the national interests are well-served by the pioneering academic research typically supported by NSF.

There are fundamentally four rationales for public support of basic pioneering research. First of all, we are all interested in the fundamental answers to enduring questions about the universe, about nature, man and so on. Second, typical American interest is in being a pioneer, being at the forefront of things. That, of course, was put to us by Vanever Bush. Third is the usefulness of science, the tremendous practical impact it has on our daily lives. And fourth is the political appeal of many scientific projects.

Now, much of the current misunderstanding in my view comes from the simple fact that scientists and politicians, like much of the public, have exactly reversed priorities among these four rationales. My position again is that the dichotomy is false. Both parties can have their way. How do you reconcile these things?

First of all, I want to point out to you that when you go into laboratories where the research is actually done, most of these distinctions lose their meaning. Nature simply does not reveal its secrets preferentially one way or the other.

When I ran a corporate laboratory, I used to challenge people who visited it to go into the laboratory, simply observe what the scientists were doing, the calculations they were making, the thoughts they were having, the experiments they were doing, and judge from that whether it was basic or applied. It is hard to do. Nature does not care what labels and motivations are—only how good and clever you are at asking the right questions, devising the right experiments, and inventing the right ideas.

The basic science, the academic researcher, is good at ferreting out secrets of nature that are both interesting and useful. The scientist approaches questions by experimentation, by understanding, by discovering the pragmatist approaches, and by trial and error, inventing, improvising.

One of my favorite examples is Irving Langmuir, the first U.S. industrial chemist to win a Nobel Prize. Early in his career at General Electric, the research director asked Irving Langmuir to solve a problem of blackening light bulb, and he handed him a blackened light bulb. Langmuir, being a scientist, did not approach that simply by building bulbs of different sizes and configurations, and filaments of different configurations. He went back into his laboratory and started trying to understand the physics and chemistry of what was going on in that light bulb. He was worried. He kept coming back to the lab director, saying, "I do not know whether I am making progress." The lab director had enough vision to saying, "Irving, keep working on it." In the end, he not only learned enough about nature to solve that problem in a simple way, a way that would never had occurred to him had he taken a straightforward approach that probably would have been better understood by his industrial leaders, but he not only solved the problem, but also launched the line of research that led to modern surface chemistry and won him a Nobel Prize.

The lesson is simple: You may point to the problems you would like scientists to address, but then leave them alone. Trying to tell them what not to do, or to steer them too closely, is like telling a salesman to quit calling on customers who are not going to buy. It just does not work.

In practice, the right way to harmonize the divergent interests of politicians and scientists is to let agency heads and administrators worry about the purposes, and let scientists worry about getting ideas and doing experiments.

Broad goals should flow from top down. What to do about them should be decided at the bottom. You should let scientists be scientists. They have produced in the past, and they will produce in the future.

We need to constantly remind ourselves of our fallibility. Tom Watson, the man who led IBM into the computer industry, in 1943 made the following statement: "I think there is a world market for about five computers." In fact, Fortune Magazine recently reported, and I quote: "In 1991, companies for the first time spent more on computing and communications gear than on industrial, mining, farm and construction machines."

The CHAIRMAN. Give that to us again, please.

Senator MIKULSKI. This is a phenomenal statement.

Mr. SCHMITT. I am quoting Fortune, and it said: "In 1991, companies for the first time spent more on computing and communications gear than on industrial, mining, farm and construction machines." That was the April 4th issue of Fortune. The same one reports that the cost of the microelectronics in an automobile today is more than the cost of steel in an automobile.

The CHAIRMAN. Less than health care, probably, though. [Laughter.] I am sorry to interrupt you.

Mr. SCHMITT. I am sorry, I do not have that number. You may be right.

What I want to point out to you is that the history of the emergence and growth of microelectronics that an automobile has more of now than it does steel, the history of that is filled with Nobel Prize-winning scientific discoveries that launched the subsequent industry-creating, job-creating, life-enhancing revolution.

Why is NSF so important today? To create new jobs, one must discover and meet new needs, create new markets, introduce new kinds of products, and launch new industries, rather than focus solely on refining current ones. Science and technology are the most important sources of these job-creating new industries.

Where do these pioneering innovations come from? In the past, they have come mostly from the corporate laboratories of major corporations like AT&T, IBM, General Electric, Corning, DuPont, and from research universities, and some of those universities are kind of interesting—the University of Pennsylvania; Stanford; the University of Alabama at Huntsville, which made a pioneering discovery in high-temperature superconductivity; the State University of New York at Stonybrook, which pioneered magnetic resonance imaging. These breakthroughs include many and most of the pioneering discoveries you know of. But in the 1980's, the corporate laboratories, responding to the demands of financial markets and the realization that Japanese companies were beating us in near-term, commercial R and D, reduced their time horizons. As a result, these laboratories have become less venturesome.

Research universities also ran into trouble in the 1980's. They became increasingly troubled despite the fact that there was significant growth in financial support for their research. But the Federal portion of that has dropped from about 68 percent in 1980 to 58 percent in 1991. Academic institutions have had to spend more and more of their own money on their research, and that, coupled with all the other financial pressures they are hitting today, is the thing that is really causing many of their problems.

I believe that NSF, as one of the principal sources of funding for this pioneering academic research, is becoming more and more vital to our Nation if we are to continue creating new, job-creating industries in the future.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

[The prepared statement of Mr. Schmitt appears at the end of the hearing record.]

The CHAIRMAN. Dr. Bush, go ahead.

Mr. BUSH. Thank you for the opportunity to testify today on the role of the National Science Foundation.

Speaking as one member of the American business community, and more particularly of the consumer products industry, I want to underscore the fundamental importance of the NSF's support of research and education to the competitive success of American business in the global marketplace. In support of this view, my testimony will illustrate the following three points, using as my example a family of shaving products recently introduced by my company.

The three points are: 1) the contributions of basic research funded by the National Science Foundation to the innovation of valuable consumer products; 2) the crucial importance of providing for the training of the high-level technical people who enabled us to apply the knowledge derived from this research; and 3) the increasingly critical role of strengthening the basic competence of the American work force in science and mathematics.

I would like to begin by describing my company. Founded in 1901, Gillette is a global consumer products company. We are headquartered in Boston, where our largest production facility for blades and razors is located. We also conduct research in our laboratory in Gaithersburg, MD. Our products are distributed in more than 200 countries and territories. Net sales last year totalled $5.4 billion, and we employ about 33,000 people worldwide, of whom about 900 work in the technical organizations of the company.

We invest substantially in research and development. Last year, for example, spending in this area amounted to $133 million, approximately 2.4 percent of our net sales.

As an indicator of the effectiveness of our approach, 37 percent of our 1993 sales came from products introduced in the last 5 years. We perform no basic research. We fund very little basic research, and that which we do is generally funded through our participation in consortia. However, I hope to convince you by my testimony not only that given enough time, the results of basic research may show up in consumer products, but also that the ability to recognize and apply relevant basic research results quickly is part of the technological know how that is essentially to our business success.

Let me take as an example three new shaving products that we collectively designate as the Sensor family. The first member, the Sensor shaving system, was introduced in 1990. It has proven to be the most successful product introduced in the history of the company. In 1992, Sensor for Women, which has also been extremely successful, was launched, and in 1993, Sensor Excel. There is an example of Sensor Excel that you can see; it happens to be one packaged for export to Japan, but it is the product that we make in our Boston factory.

The CHAIRMAN. Can we keep these?

Mr. BUSH. Absolutely. We would like your consumer feedback, please. [Laughter.]

The Sensor Excel is now available in European markets and in Canada, where it is doing well, and it will be introduced in the United States later this year, so you will be among the first in this country to be able to try it.

In 1993, the worldwide sales volume for these products was about $700 million. There are some 950 people in our South Boston plant who are directly connected with the production of this family of products.

What role did NSF-funded research play in this highly successful innovation? For many years, the NSF has funded basic work in disciplines such as chemistry, metallurgy, and material science, polymer physics, and materials characterization and analysis at universities. The results of this work are reflected in the Sensor family of products in many ways. For example, the process we use in our factory to treat the stainless steel used in the blades derives from principles revealed by work the NSF funded at the University of California at Berkeley more than 30 years ago. Our understanding of the plasma deposition process used to coat these blades with a hard intermetallic compound is based in part on NSF-funded work at UCLA more than 15 years ago.

I was going to demonstrate, but in the interest of time, I would suggest if you want to verify what I am saying that you unpackage at your leisure and observe how these products work. But one of the distinctive features of the Sensor family is the floating action of the blades. To accomplish this action, plastic springs are integrally molded into the cartridge. When a potentially serious issue arose concerning the solvent-induced stress-cracking behavior of these plastics, information that resulted from research funded by the NSF at MIT was valuable to us in avoiding the problem.

To support the blades and plastic springs, it proved economically efficient to weld them to small supports. If you later are able to examine one of the blades, you will see a series of 13 dots which are indications of these welds. We found that laser welding is an economical and reliable way to carry out this task. While I cannot make a direct connection with the commercial lasers we use in our metal joining and forming operations, it seems very likely to me that some of the university research on lasers and laser materials funded by the NSF was instrumental in their now widespread industrial application.

Another example is provided with our experience with the Sensor for Women razor. This handle is made by a process called injection molding that involves squirting molten plastic into a metal form where it is cooled to the solid State in the desired shape. When a problem with the appearance of the handle surfaced rather late in the program, our ability to analytically model the injection molding process and evaluate alternative solutions by computer simulation in time to meet the launch schedule was very valuable to us. The analysis was performed with a commercial software program called C-flow, which comes directly from NSF-funded work at Cornell University.

The written testimony which I have submitted separately includes some further examples.

Briefly, I would like to summarize some of the things I think this suggests. One, there is no short, straight line between research and its application in consumer products. However, one should not, in my view, conclude from this that one piece of technical knowledge is likely to be as commercially useful as another piece.

Two, knowing the right technical facts at the right time is valuable. Because we were committed—or have a strategic goal, if you prefer that language—to innovate a breakthrough shaving product, we mapped out the possible outcomes based on the knowledge we had and designed a program to get additional knowledge that we needed to get the job done. In effect, we placed a series of bets that working in particular technical areas would pay off for us, and then we hedged those bets when we thought the stakes warranted them.

Three, the judgment of economic factors is as important as technical judgment to innovating a consumer product. Economic judgments about outcomes are important to placing smart bets on technology.

In the text I have submitted, I comment on the stakeholders involved in this process, and I will amplify on that, I hope, in a moment, but I would like to suggest that it occurs to me that the National Science Foundation needs to devise a suitable political process to integrate the views of the stakeholders throughout the NSF programs that fund basic research. Such a process could, if properly designed, hasten the transfer of research results into application in industry. Steps in that direction have been taken by the engineering directorate through its sponsorship of centers and through its inclusion of industrial representatives in the peer review process. This recommendation is consistent with the report that the committee on industrial support for R and D made to the National Science Board in 1992, and we strongly endorse the recommendations of that report.

Categorizing NSF program support by strategic themes seems to me to be a useful start toward a new process for aligning the interests of the stakeholders in the outcomes of basic research. However, how determines the strategic goals and how particular projects are selected against those goals are issues that I believe deserve wide discussion.

Based on my own experience, I am also concerned that strategic goals could become a strategic straightjacket. It therefore seems to me that the NSF should consider establishing a strategic goal with regard to science itself, to bring into being those fields of research that break out of the patterns and assumptions of normal science and technology. It is from supporting research toward this goal that I would expect new disciplines, redirection of the agendas of established disciplines, and discontinuous innovation—the lasers and transistors of the future.

As I stated at the beginning of my testimony, we believe it is crucially important that the American research universities continue to produce high-caliber people, trained in research disciplines of value to us. We employ some 37 Ph.D.s in Boston and Gaithersburg, and approximately two-thirds of them have been involved in work related to the Sensor family. They come from disciplines as diverse as chemical engineering, polymer science, metallurgy, mechanical engineering, physics, electrical engineering, and neurophysiology. For many of them—about 40 percent—the United States is not their native country, but such places as India, China, South Africa, Greece, and Vietnam. However, in each case, their graduate education was received at one of the research-intensive American universities—the University of Massachusetts, MIT, Harvard, Johns Hopkins, Howard, Carnegie Mellon, Ohio State, Michigan, and Wisconsin, for example.

By their role in developing new products such as the Sensor family, these skilled people are helping to create opportunities for well-paying, meaningful jobs in the United States.

The third aspect of the NSF mission which I want to stress today is that of providing a sound basis for competency in mathematics and science for people entering the work force. It is commonplace to note that our schools generally are not adequately preparing graduates to function in a workplace that demands some proficiency in science or mathematics. The launch of the Sensor family brought that home to us. Before we could start production, we had to develop mathematics classes for our employees to do certain calculations—arithmetic, percentages and the like—required to run the machinery to make the product. Usually in the startup of a new production process, the rate at which special machinery can be built determines the rate at which we can wrap up production. Contrary to that experience, for a time, we found that we were being paced by the rate at which we could train our work crews.

While we have been successful with retraining current employees for more demanding tasks, we are finding that people seeking employment are increasingly ill-prepared academically to discharge the responsibilities involved in entry-level jobs. We are participating in a number of initiatives to upgrade the quality of schools in and around Boston, but the task is a daunting one. It will need the creative involvement of all concerned, including importantly, the National Science Foundation.

In summary, I urge the strengthening of the NSF to carry out with greater effectiveness its research and education mission, providing for basic research that meets the needs of the three principal stakeholders—American industry, the Federal Government, and American research universities—also, by creating a cadre of technically skilled, creative people who can translate knowledge into products and processes and relate business competitiveness and income growth to technically; and finally, by equipping America's citizens with the basic scientific and mathematical competence to form an increasingly productive work force, working in meaningful jobs and acting as responsible, informed citizens.

Thank you.

The CHAIRMAN. Thank you very much.

[The prepared statement of Mr. Bush follows:]

PREPARED STATEMENT OF JOHN B. BUSH, JR.

Thank you for the opportunity to testify today on the role of the National Science Foundation. I am John B. Bush, Jr., Vice President, Corporate Research and Development, of The Gillette Company.

Speaking as one member of the American business community, and more particularly of the consumer products industry, I want to underscore the fundamental importance of the NSF's support of research and education to the competitive success of American business in the global market place. In support of this view, my testimony will illustrate the following three points using as my example a family of shaving products recently introduced by my Company. The three points are:

1. The contributions of research funded by the NSF to the innovation of valuable consumer products.

2. The crucial importance of providing for the training of the high level technical people who enable us to apply the knowledge derived from this research.

3. The increasingly critical role of strengthening the basic competence of the American workforce in science and mathematics.

I would like to begin by describing my Company. Founded in 1901, Gillette is a global consumer products company. We are headquartered in Boston, where our largest production facility for blades and razors is located. We also have a research laboratory in Gaithersburg, MD. Our products are distributed in more than 200 countries and territories. Net sales last year totaled $5.4 billion, and we employ about 33,000 people worldwide, of whom about 900 work in the technical organizations of the Company.

We invest substantially in research and development—last year, for example, spending in this area amounted to $133 million, approximately 2.4 percent of our net sales. As an indicator of the effectiveness of our approach, 37 percent of our 1993 sales came from products introduced in the last five years.

We perform no basic research. We fund very little basic research and that which we do is generally funded through our participation in consortia. In this regard I believe we "move at a slower technological pace and require few inputs from current science" but "require the highest levels of technological and production know-how".[2] By the example I hope to convince you however not only that, given enough time, the results of basic research may show up in consumer products but also that the ability to recognize and apply relevant basic research results is part of the technological know-how that is essential to business success.

Let me take as an example three new shaving products that we collectively designate as the Sensor family. The first member, the Sensor shaving system, was introduced in 1990. It has proven to be the most successful product introduced in the history of the Company. In 1992 Sensor for Women, which has also been extremely successful, was launched and in 1993, Sensor Excel. The Sensor Excel shaving system is now available in European markets and Canada where it is doing well. It will be introduced in the United States later this year. In 1993 the worldwide sales volume for these products was about $700 million. There are some 950 people in our South Boston plant who are directly connected with the production of this family of products.

What role did NSF-funded research play in this highly successful innovation? For many years the NSF has funded basic work in disciplines such as chemistry, metallurgy, and material science, polymer physics, and materials characterization and analysis at universities. The results of this work are reflected in the Sensor Family of products in many ways. For example the process we use in our factory to treat the stainless steel used in the blades derives from principles revealed by work the NSF funded at the University of California, Berkeley, more than thirty years ago. Our understanding of the plasma deposition process used to coat these blades with a hard inter metallic compound is based in part on NSF funded work at UCLA more than fifteen years ago.

To accomplish the floating action of the blades in the Sensor family, springs are integrally molded into the cartridge, When a potentially serious issue arose concerning the solvent induced stress cracking behavior of these plastics, information that resulted from research funded by the NSF at MIT was valuable to us in avoiding the problem.

To support the blades on the plastic springs it proved economically efficient to weld them to small supports. If you examine one of the blades you will see a series of thirteen dots, which are indications of these welds. Two of the dots are hidden by the ends of the cartridge. We found that laser welding is an economical and reliable way to carry out this task. While I cannot make a direct connection with the commercial lasers we use in our metal joining and forming operations, it seems very likely to me that some of the university research on lasers and laser materials funded by the NSF was instrumental in their now widespread industrial application.

Another example is provided by our experience with the Sensor for Women razor. The handle is made by a process called injection molding that involves squirting molten plastic into a metal form where it is cooled to the solid state in the desired shape. When a problem with the appearance of the handle surfaced rather late in the program, our ability to analytically model the injection molding process and evaluate alternative solutions by computer simulation in time to meet the schedule was very valuable to us. The analysis was performed with a commercial software program called C-flow which comes directly from NSF funded work at Cornell University.

The written testimony includes some further examples of the ways in which the results of NSF funded basic research were applied to these products.

The Sensor example suggests some conclusions about the role of basic research and scientific knowledge in innovating new consumer products.

There is no short straight line between research and its application in consumer products. In fact, useful as they all were, no single technique or piece of knowledge determined the outcome. There was no "breakthrough" in research that made Sensor possible. However, one should not, in my view, conclude from this that one piece of technical knowledge is likely to be as commercially useful as another.

Knowing the right technical facts at the right time is valuable. What became the Sensor shaving system went through six distinct forms over a period of four years and it triumphed over at least four distinct alternative concepts. With perfect hindsight, one could question why we did not go directly to the solutions that we finally used in Sensor. Because we were committed, had a strategic goal if you prefer that language, to innovate a breakthrough shaving product, we mapped out the possible outcomes based on the knowledge we had and designed a program to get the additional knowledge we needed to get the job done. In effect, we placed a series of bets that working in particular technical areas would pay off for us and then we hedged those bets when we thought the stakes warranted it.

Judgement of economic factors is as important as technical judgment to innovating a consumer product. Economic analysis of alternatives, based on information, heuristics, knowledge of consumer behavior, in short the embedded knowledge of the shaving business was at least crucial to the final success of the Sensor family as the technical knowledge applied in its creation. Economic judgments about outcomes are important to placing smart bets on technology.

As a manager, I must be able to answer the question: What research should be supported today so that the kinds of benefits that we applied in the development of the Sensor family may be obtained for products and processes that are not yet even concepts? Stated from the perspective of Congress, that question might become: what criteria should be used to select research which produces results that further the economic success of America? There are many stakeholders with interests in the way that question is answered. As a user of the knowledge from NSF-funded research, I am a stakeholder in its outcomes. Members of the academic community are most emphatically stakeholders in the outcomes. The federal government in carrying out its goals regarding competitiveness and job creation is a stakeholder. It occurs to me that the NSF needs to devise a suitable political process to integrate the views of the stakeholders throughout the NSF programs that fund basic research. Such a process could, if properly designed, hasten the transfer of research results into application in industry. Further steps in that direction have been taken by the Engineering Directorate through its sponsorship of Centers and through its inclusion of industrial representatives in the peer review process. This recommendation is consistent with the report of a Committee on Industrial Support for R&D to the National Science Board in 1992 [3] We strongly endorse the recommendations of that report.

Categorizing NSF program support by strategic goals seems to me to be useful start toward a new process for aligning the interests of the stakeholders in the outcomes of basic research. Who determines the strategic goals and how particular projects are selected against those goals are issues that I believe deserve wide discussion. Based on my own experience, I am also concerned that strategic goals could become a strategic straitjacket. It therefore seems to me that the NSF should consider establishing a strategic goal with regard to science itself—to bring into being those fields of research that break out of the patterns and assumptions of normal science and technology. It is from supporting research toward this goal that I would expect new disciplines, redirection of the agendas of established disciplines, and discontinuous innovation - the lasers and transistors of the future.

As I stated at the beginning of my testimony, we believe that it is crucially important that the American research universities continue to produce high caliber people trained in research disciplines of value to us. We employ some 37 PhDs in Boston and Gaithersburg and approximately two thirds of them have been involved in work related to the Sensor family. They come from disciplines as diverse as Chemical Engineering, Polymer Science, Metallurgy, Mechanical Engineering, Physics, Electrical Engineering, and Neurophysiology. For many of them (about 40%) the United States is not their native country but such places as India, China, South Africa, Greece and Viet Nam. However, in each case their graduate education was received at one of the research intensive American universities: University of Massachusetts, MIT, Harvard, Johns Hopkins, Howard, Carnegie Mellon, Ohio State, Michigan and Wisconsin for example. By their role in developing new products such as the Sensor family, these skilled people are helping to create opportunities for well paying, meaningful jobs in the United States.

The third aspect of the NSF mission which I wanted to stress today is that of providing a sound basis for competency in mathematics and science for people entering the workforce. It is commonplace to note that our schools generally are not adequately preparing graduates to function in a workplace that demands some proficiency in science or mathematics. The launch of the Sensor family brought that home to us. Before we could start production we had to develop mathematics classes for our employees to do certain calculations—arithmetic, percentages and the like—required to run the machinery to make the product. Usually in the start-up of a new production process the rate at which special machinery can be built determines the rate at which we can ramp up production. Contrary to that experience, for a time we found that we were being paced by the rate at which we could train our work crews. While we have been successful with retraining current employees for more demanding tasks, we are finding that people seeking employment are increasingly ill-prepared academically to discharge the responsibilities involved in entry level jobs. We are participating in a number of initiatives to upgrade the quality of schools in and around Boston but the task is a daunting one. It will need the creative involvement of all concerned, including importantly the NSF.

In summary I urge the strengthening of the NSF to carry out with greater effectiveness its research and education mission:

Providing for basic research that meets the needs of the three principal stakeholders: American industry, the federal government, and American research universities.

Creating a cadre of technically skilled, creative people who can translate knowledge into products and processes and relate business competitiveness and income growth to technology and,

Equipping America's citizens with the basic scientific and mathematical competence to form an increasingly productive workforce, working in meaningful jobs and acting as responsible, informed citizens.

Thank You

[1] See for example J. Carey, "Could America Afford the Transistor Today?" Business Week, March 7, 1994, pp 80-84

[2] Committee on Science, Engineering and Public Policy, Science, Technology and the Federal Government: National Goals for a New Era, Washington: National Academy Press, 1993, p 11

[3] Committee on Industrial Support for R & D, National Science Board, The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues, NSB 92-138, August 1992, pp 52-54

The CHAIRMAN. That is a good introduction. Dr. Davidson, we are going to be considering the Goals 2000 bill in a couple of hours, and obviously, we are going to be considering content standards issues as well as assessments. I know you have been doing a lot of thinking about some of these issues. I did not ask the director earlier about what NSF is doing in math and science in the development of content standards, and if you would make some comments on that as well, as it is appropriate, I would appreciate it.

Mr. DAVIDSON. Thank you, Senator Kennedy, Senator Mikulski. I am here to speak on behalf of the Statewide Systemic Initiatives Programs, which are forerunners of the Rural Systemic Initiatives and the Urban Systemic Initiatives, using Louisiana as an example.

As many of you know, Louisiana has not historically been a national leader in the quality of its K through 12 educational system. Many indicators of quality, unfortunately, place Louisiana toward the negative end of the spectrum regarding such matters as the rate of illiteracy, the rate of poverty, the rate of high school dropouts, the rate of teenage pregnancy, the rate of crime, and scores on national tests.

The one category in which we rank unmistakably as number one is in the need for school reform. For these reasons, Louisiana may be considered an ideal test case for the systemic reform program. If it can happen in Louisiana, it should at least be possible elsewhere.

Last weekend, I participated in a 3-day conference of national and State leaders involved in the systemic reform movement. We periodically meet to exchange views across States with program officers at NSF and with other national leaders. One issue we pondered at this conference was how to communicate effectively the meaning of systemic reform to policymakers, particularly since we as reformers are daily learning so much about the magnitude of the effort before us.

One knowledgeable estimate is that continuing revolutions in technology will require a 90 percent change in the content and classroom practice of K through 12 mathematics, and almost as much change in science. The still developing hand-held graphing calculator and computer will eventually remodel the learning of 9 through 12 mathematics and science, as much as the four-function calculator will change K through 8 mathematics.

These devices are transforming what students need to know for the 21st century and how students will acquire that knowledge. Together with other advances in technology, the dramatic impact on learning for the 21st century will be comparable to the effect which the advent of the automobile has had on travel during the 20th century.

The difficulty in shifting thought from one major paradigm to another may be appreciated if we recall that the automobile was first known as "the horseless carriage."

Within this context, traditional approaches to the teaching of mathematics and science in schools have largely become irrelevant. Guided by national standards, the SSI program in Louisiana has focused on the redirection of student learning away from paper and pencil drill and rote memorization toward hands-on problem solving, communicating, reasoning, and critical thinking. The students impacted are not only developing an enthusiasm for mathematics and science; they also exhibit a spirit of inquiry, the curiosity for understanding, and receptivity for future change, all vital components of lifelong learning.

The touchstone of the SSI program in Louisiana and the others across the Nation is to make these innovative learning approaches accessible to all students. The SSIs must be understood, therefore, not as projects or programs in the traditional sense, but rather as the driving force to change school culture and the broader culture to accord with learning demands of the 21st century.

It is further noteworthy that the SSIs are the vanguard of the Goals 2000 movement. Standards-based reforms in mathematics and science are paving the way for transitions which are also essential to other disciplines. At every level, these questions regarding the SSIs are logically and inevitably posed.

Are changes of this magnitude feasible? Are they sustainable? My written testimony emphasizes the success of Louisiana's program in establishing 29 professional development projects for teachers throughout the State. These have been competitively funded, based on a peer review process. We have engaged the services of more than 120 out-of-State experts from 33 States to help ensure that the projects provided for teachers are shaped by evolving national standards in mathematics and science.

These projects have now provided professional development for over 1,600 teachers, who in turn have impacted over 120,000 students and classrooms. Early test results indicate that 5th and 7th grade students who are taught by teachers in the Louisiana program scored higher on a recent statewide mathematics test. Another result significantly has been entirely serendipitous. University faculty involved in summer projects for teachers have now begun to modify their college-level curricula for prospective teachers as well as other students.

I will add two vignettes which bear on the issues of feasibility and sustainability. One is a recent letter to me from the principal of an upper elementary school in Raceland, LA. Including surrounding suburbs, the population of Raceland is approximately 5,500. This letter was transmitted to me via Raceland's only fax machine, located at the hospital where the principal's wife works. With the constraint of time, I will simply read one paragraph from the letter, and I would like to note that the students are 47 percent black and 53 percent white.

I quote: "You may be interested in the following information. Our 5th grade California Achievement Test scores in science for the 1992-1993 school session increased by 41 percentile points. Our 6th grade scores for that year increased 30 percentile points from the previous year. This year, 1993-1994, as of the second 9 weeks, our 5th grade scores have increased by 21 percentile points. Our 6th grade scores have increased by 32 percentile points. I attribute these increases to the implementation of the SSI Louisiana program."

The second vignette is a product of a survey of mathematics teachers in East Baton Rouge Parish or county, which illustrates the bang we are getting for the bucks you have helped provide. The context is this. First, out of a $4 billion budget for K through 12 education in Louisiana, including State, local and Federal resources, the moneys devoted to Louisiana's SSI program constitute one-half of one-tenth of one percent.

To understand this vignette, it is relevant to note that the original LaSIP professional development model, which has now been disseminated statewide for both math and science, was developed and implemented at the middle school level in East Baton Rouge Parish by several mathematics professors from Louisiana State University.

The project has provided direct professional development to only a small portion of middle school teachers in that parish. Yet a recent survey throughout the parish indicated that 50 percent of middle school mathematics teachers considered the NCTM national standards as the primary influence which shaped the way they teach. At the elementary and high school levels, however, where the SSI program has not had sufficient resources to extend the reform method, only 22 percent and 29 percent, respectively, indicated that the national standards were the primary influences on their teaching.

We are confident that the evidence from Raceland Elementary and the survey among mathematics teachers in one parish reflect the overwhelming evidence statewide that LaSIP professional development projects are having a rippling effect. Classrooms and the school culture are changing.

The SSI program has become a galvanizing message of hope in an environment of despair, an antibiotic which is pervading the revitalizing the system.

The future of long-term sustainability, as we know, is a projection into the future which no one can answer with absolute certitude. Yet the teachers at Raceland, the middle school mathematics teachers in East Baton Rouge Parish, and the university faculty who are revising their courses will not revert to traditional approaches because NSF moneys are no longer available. And the parents whose children are scoring higher on mathematics tests will not be silent if the process which produced these results is reversed.

In these and many other ways, the Louisiana landscape is changing in an unprecedented and irreversible manner. Even an oak tree, however, has to have time to extent its roots before it is certain to withstand the inevitable storms and winds. And as we have learned from those wiser than we, all educational reform, like all politics, is ultimately local. We need more Racelands to dramatize that reforms are translated into more effective student performance. We need higher percentages of teachers committed to national standards at the elementary and high school levels, in science as well as mathematics.

I personally believe that two 5-year cycles of combined NSF-State funding are needed in Louisiana to ensure this result.

In conclusion, in light of the transforming impact of technology, and in light of the growing consensus that schools, notwithstanding notable pockets of quality, are generally considered outmoded and anachronistic, maintenance of the present system is not feasible or sustainable.

Systemic reform is an idea whose time has come. What has not been resolved is the nature of changes on the horizon. Whether the commitment of SSIs to prepare all students for life and careers in the 21st century will be realized, or whether more exclusive options will be chosen, viewed in this perspective, the central issue becomes not whether the SSIs can be successful, but rather that the stakes are so high that they cannot be allowed to fail.

Thank you for the opportunity.

[The prepared statement of Mr. Davidson follows:]

Prepared Statement of Dr. Kerry Davidson

I. INTRODUCTION

Chairman Kennedy, and members of the committee, I welcome the opportunity to testify on behalf of legislation to reauthorize goals and programs of the National Science Foundation, in particular the SSI programs which represent a fundamental change of thinking in the nation's attempts to strengthen mathematics and science education. The essential premise of SSI is that systemic barriers hamper efforts to prepare students for life and careers in the 21st century; these barriers can be overcome only by strategies of investment and change which are themselves broad and comprehensive, i.e. systemic.

The SSI program in Louisiana (LaSIP) was one of the first ten which NSF funded during 1991. The purpose of this testimony is to examine the statewide impact which LaSIP and similar programs have had during the first two and one/half years.

II. PARTICIPATING SSI STATES

The State Systemic Initiative (SSI) Program, inaugurated by the NSF in FY 1991, currently consists of 25 states and Puerto Rico (see Appendix A). These programs represent efforts to relate the major components of successful science and mathematics education: teacher enhancement, curriculum development, standards and assessment, underrepresented population development, informal education, educational technology and public awareness/outreach. While the program in each state is unique, all 551 programs are drawn together by these common goals and initiatives.

III. OVERVIEW OF THE LOUISIANA SYSTEMIC INITIATIVES PROGRAM (LASIP)

The Louisiana Systemic Initiatives Program (LaSIP) is a five-year, $20 million plus undertaking to reform the teaching and learning of mathematics and science consistent with the rapidly changing needs of the age of technology. LaSIP embraces and emphasizes the major dimensions of systemic reform. The scope of the reform endeavor is, therefore, systemwide, involving policymakers, professors, administrators, classroom teachers, the business community, and other stakeholders. LaSIP has served as a catalyst to encourage universities and school systems to coalesce into effective lasting partnerships, and to embrace, thereby, the diverse constituencies with which schools and colleges interact.

This report assesses accomplishments, challenges, and prospects within the context of relevant demographic data. Implementation of national standards and concepts for mathematics and science education has remained LaSIP's guiding goal. Professional development for teachers, as the most powerful catalyst to directly impact learning, has been LaSIP's highest priority. The development of curriculum and related assessment frameworks and the reform of teacher preparation have now joined professional development as premier priorities. For these and other areas, significant evolutions in insights and approaches have occurred.

The unfolding of trends at the national level, the deepening of perspectives through day-to-day experience, and evolving funding opportunities have all helped reshape the initial contours of LaSIP. Evolving priorities and programs of LaSIP reflect, therefore, expanding and transforming goals of reform.

A. SCHOOL DEMOGRAPHICS FOR LOUISIANA

—The state has over 50,000 teachers and almost 900,000 students.

—The Afro-American school population is over 40 percent compared to approximately 16 percent nationally.

—The disadvantaged urban population is 23 percent compared to 10 percent nationally.

—More than 50,000 school-aged children live in homes where English is the second language.

—Louisiana has the highest rate of illiteracy in the nation (adults with less than five years of schooling) and the third highest rate of teenage pregnancy.

—Less than 60 percent of the seventh graders subsequently graduate from traditional state high schools.

—The educational system has a strong centralized basis.

—The legislature has mandated both statewide curricula and assessment.

—Louisiana is one of only 10 states that requires 3 mathematics credits for high school graduation; and one of only 3 states that requires 3 science credits for high-school graduation.

—The most advanced degree for approximately 58 percent of public school teachers is a bachelor's degree.

—More than 30 percent of the science teachers and 15 percent of the mathematics teachers are not certified in their fields.

—Lifetime certification for teachers is granted after three years.

—The average teacher salary and per pupil expenditure rank 42nd in the nation.

—The 1992 NAEP results in mathematics rank the state 40th of the 41 states tested.

B. ORGANIZATION AND MANAGEMENT

The program is governed by the LaSIP Council, a statutory body of 29 members representing all major stakeholders. The Council is chaired in alternate years by the Chairman of the Board of Regents (BoR) and the President of the state Board of Elementary and Secondary Education (BESE). The formal and philosophical mandate of the Council is to recommend, support, and effect standards-based reform of mathematics and science education. Where changes in legislation and other policies are deemed essential, the Council recommends such changes to the appropriate governing authority.

Objective indices support the Council's efficacious role of leadership, and the strong supporting roles of BESE and BoR. The Board of Regents, which is providing $5 million for LaSIP and $2.5 million for the Louisiana Collaborative for Excellence in the Preparation of Teachers (LaCEPT), has voted seven times during 1991-93 on matters relating to mathematics and science education reform. Each vote of the 16-member Board has been unanimous. On each occasion during 1991-93 when the BESE has voted to establish or to continue annual funding for LaSIP, the vote of the 11-member Board has been unanimous. After competitive reviews, the LaSIP Council has authorized funding for 49 professional development projects, 8 MSEA projects, and 22 Local Systemic Sites. Each of these votes has been without dissent.

During December 1993, the following query was posed to each member of the BoR and the BESE: "I view the overall impact of LaSIP on mathematics and science reform as either highly positive, positive, acceptable, or not acceptable." Twenty-five of the 27 board members replied, and all 25 judged the impact of LaSIP to be either highly positive or positive. Each respondent, notably, represents and interacts with sizable constituencies.

In many respects the fiscal management of LaSIP, like other components, has also required the intermeshing of disparate "systemic" elements. Coordination among multiple of funding sources, fiscal agents, fiscal years, accounting philosophies and practices has not always been simple to accomplish. Unplanned delays in the disbursement of funds have occurred. The strength of LaSIP has been unequivocal support from chief executive officers and their governing bodies. The major hurdles to efficient financial management are, therefore, being addressed and overcome.

C. STRATEGIES OF IMPLEMENTATION

LaSIP employs a systemic approach to the achievement of standards-based reform. The scope of the endeavor is thus as broad as society and as dynamic as rapidly progressing insights. Traditional approaches to the implementation of specialized programs and projects cannot fully embrace the scope and complexity of this uncommon approach to reform. All targets are moving: the definition, understanding, and priorities among goals and programs; the relevance of strategies to be employed; the significance and congruence of indicators; and the correlations of these variables to interpretations and conclusions. To be valid, the process of implementation must reflect the capaciousness and orbit of systemic reform and any corrections that are made must be highlighted by both the constancy and evolution of relevant variables.

While remaining firmly anchored by the quest to achieve standards-based goals, LaSIP has combined continuity of its principal focus on professional development with significant adaptations of strategies and tactics for many other areas. Respective initiatives and programs have been revised to capitalize on leadership potential and to reflect changing phenomena-intellectual, organizational, financial, and political. As a consequence, LaSIP's strategies for the implementation of programs have always been midstream, adapting to changing realities. Evolving definitions and implications of the standards are continually reevaluated in relation to various LaSIP programs.

A variety of factors influence these choices: the insights derived from experience; the emergence of different needs; the identification of individuals with leadership qualities; new funding opportunities; and changing understandings of national trends. Within this context, the overall La SIP strategy has been to continually reassess directions while programs are in motion, to "redesign by design" as a way of recognizing the dynamic character of systemic reform.

D. INITIATIVES AND PROGRAMS

LaSIP embraces eight interrelated initiatives: professional development, teacher preparation, curricula, assessment, teacher certification, educational technology, partnerships with the private sector, and information dissemination. During the first two years of operation, each initiative was guided by a separate panel including teachers, administrators, university faculty, and other stakeholders. These panels served as focus groups to broaden awareness of the meaning of systemic reform and help LaSIP create integrated visions for respective initiatives and the entire program. Each panel developed plans and strategies to help guide systemic reform for its respective initiative. By the close of the second year, efforts to establish awareness and to formulate initial plans had been fulfilled; consequently, LaSIP restructured panel efforts—some panels were strengthened, some were combined, and others assumed redefined roles. The individual initiatives are discussed in the respective sections that follow.

III. INSERVICE/PROFESSIONAL DEVELOPMENT

Major Achievement: Over 1,600 mathematics and science classroom teachers participated in 49 LaSIP professional development projects during FY 1992-94. The typical project offers each participant 120-180 hours of concentrated, integrated exposure to both content and methods. Over 100,000 students have been directly impacted through these 1,600 teachers.

The professional development activities of LaSIP have played a vital role in establishing the credibility of the reform effort and of LaSIP itself. The budget reflects the central role of professional development, which is allocated approximately 70 percent of total LaSIP funds, including 75 percent of higher education MSEA funds.

The effort to make school mathematics and science relevant to the 21st century has encountered considerable obstacles, not the least of which has been the general lack of understanding of the depth and scope of change needed in school culture. To address this issue, professional development has provided educators the perspective and sophistication of knowledge that continually evolving national standards require. The design incorporates systematic follow-up support to assist teachers in implementing longterm changes in student learning.

LaSIP site coordinators are key elements of support. The coordinators are carefully selected, full-year project staff members with extensive classroom experience at the targeted grade level and have a demonstrated commitment to standards-based student learning. They serve as key points of contact between faculty and participants, provide feedback from journals, demonstrate classroom practice, order materials, hold academic-year workshops, and visit classrooms during the school year. The commitment, dedication, and both organized and informal networking of site coordinators are vital elements to the success of LaSIP.

Primary emphasis has been placed on projects for teachers in the middle school grades 4-8. The rationales for this decision were: (1) the critical need for reform of mathematics and science instruction at these grade levels; (2) the need to impact all students with reformed mathematics and science education to prepare citizens for the 21st century; (3) the inadequate supply of teachers qualified at these grade levels to instruct in the reform mode; and (4) the expectation that greater comfort with and understanding of mathematics and science will help reduce the high drop-out rate in Louisiana's public schools. To date, approximately 80 percent of the professional development projects sponsored by LaSIP have been targeted at these levels.

Characteristics of most professional development projects include: (1) specifically designed course content with emphasis on reasoning, investigating, and practical understanding of concepts; (2) recruitment of 30-33 current teachers of mathematics and/or science in pairs from schools; (3) summer and/or academic-year institutes providing 120 to 180 hours of concentrated, integrated exposure to grade-level relevant content and methods; (4) academic-year follow-up activities including classroom visits and day-long workshops; (5) $300 allotment per participant for classroom materials; (6) graduate credit for successful participation in most projects; and (7) stipends ($60/day) for program participants.

Although independently designed and implemented, all professional development projects are based on statewide guidelines stipulated in LaSIP's annual request for proposals (RFPs) which are transmitted to all colleges, universities, and school systems. Earlier NSF/LSU projects have served as a model on the basis of which LaSIP projects were designed. Staff of most LaSIP projects include joint involvement of mathematicians/scientists, mathematics/science educators, and site coordinators. Professional development projects are awarded competitively, based on recommendations of out-of-state consultants. The consultants review proposals and personally interview project staff. This merit based approach to the implementation of national standards is the critical axis on which the LaSIP program turns.

The statewide projects have provided professional development for teachers in each of the state's 64 parishes. In 45 of these parishes, ten or more teachers have been involved in LaSIP projects. One consequence of such empowerment of teachers is that they become change agents for, and magnets of, reform by leading workshops for other educators in their areas.

The results of separate statewide tests in mathematics for grades 5 and 7 indicate that students of LaSIP teachers are scoring slightly higher as a group than their respective grade-level populations. The test results are derived from the spring 1993 administration of the Louisiana Educational Assessment Program (LEAP) criterion-referenced tests. The LEAP test items, it should be noted, are based on a pre-reform curriculum formulated in the early 1980s; they are not designed, therefore, to measure the problem solving and critical-thinking skills being developed through LaSIP professional development projects.

Professional development provides a foundation for other reform initiatives by creating a critical mass of informed teachers, school administrators, and university faculty. During 1994, LaSIP anticipates funding a minimum of 24 additional projects directly impacting an additional 800 mathematics and science teachers.

IV. OTHER COMPONENTS

A. DIVERSITY

Major Achievement: Whereas during 1992-94, 43 percent of K-12 students in Louisiana schools have been minority students, 48 percent of the students impacted by teacher-participants in LaSIP Professional Development Project have been minorities.

While diversity has permeated all components of LaSIP, the issue is emphasized separately due to its importance and because of the significant evolution in LaSIP's approach to this matter. A priority of LaSIP has been to enhance the teaching and learning of school mathematics and science for all students, in particular those from traditionally underrepresented groups. The primary effort to date has been through professional development projects that focus on teachers and students in grades 4-8, reaching all students during a critical formative stage.

A goal has been to reflect ethnic, gender, and geographic diversity through representation on LaSIP's key governing and advisory bodies and in all of LaSIP's programs and activities, as evidenced below:

—Women and minorities serve as chairs and co-chairs of a number of panels and steering committees, and are well represented on all out-of-state review teams, program evaluation teams, and in-state reviews.

—On March 10, 1992, the LaSIP Council adopted the policy that "LaSIP shall provide special assistance to Historically Black Colleges and Universities (HBCUs) in order that they may exercise leadership roles in addressing the needs of Louisiana's black population."

—LaSIP's RFP requires that all funded programs actively recruit both minority teachers and teachers of minority and underrepresented students, and that attention be given to gender and ethnic differences in learning styles.

—Activities that promote an understanding of diversity ad differences in students' learning styles have been modeled at statewide meetings for site coordinators and other key change agents.

—To ensure cultural sensitivity in the mathematics ad science frameworks, a Louisiana Equity Review Team has been established to review framework documents and to provide technical assistance during development.

—To enhance the learning of all students and, in particular, to narrow the gap between the "haves" and the "have nots," LaSIP has developed an Action Plan for Equity and Diversity Awareness and Training. During the spring of 1994, three conferences, to be attended by LaSIP staff and/or professional development project directors and their staffs, will address ethnic and gender diversity issues.

LaSIP has successfully included representation of females and ethnic minorities in every dimension of its program. This accomplishment, though significant, remains insufficient. Additional efforts are needed to address gender and ethnic attitudinal biases that result in negative learning signals for many students.

B. TEACHER PREPARATION

Major Achievement: As an indirect outcome of the LaSIP initiatives, the "Louisiana Collaborative for Excellence in the Preparation of Teachers" (LaCEPT) was funded by NSF in March 1993. The five-year, $4 million NSF grant was matched with state funds from the Board of Regents of $2.5 million.

To effect systemic reform, LaSIP has always recognized the necessity of a major redesign of teacher preparation toward standards-based lifelong learning and future change. That redesign must focus on the special issues, problems, and opportunities at the college and university levels.

LaSIP's focus on 4-8 grade-level professional development has provided a springboard for radical rethinking of preservice programs. University mathematics and science faculty have, for the first time, become acutely aware of the needs of teachers; this more sensitive understanding has led to new goals and directions for college-level curricula. For example, the chairs of the mathematics departments at Louisiana State University and the University of Southwestern Louisiana, both LaSIP professional development project directors, are leading their respective universities toward reform in teacher preparation.

Two statewide mathematics preservice conferences have stimulated inter-university discussions concerning the reform of university level mathematics, particularly addressing the graphing calculator and its implications for major changes in content emphasis. Several universities are now requiring graphing calculators for mathematics courses. In January 1994, LaSIP/LaCEPT will host a science preservice conference to discuss issues pertaining to the reform of university science.

The funding of LaCEPT, which is closely intertwined with LaSIP, has provided Louisiana with a major boost toward reform not only in preservice courses but more generally in all mathematics and science courses. The 1991-92 Board of Regents' review of mathematics and science programs, as promised in the LaSIP proposal, was a semiannual event in developing a basis for preservice reform, providing the state with baseline information from which to gauge growth. After the grant was awarded, LaCEPT instituted an internship program in conjunction with the LaSIP professional development projects. In 1993, ten college and university mathematicians and scientists served as interns in the summer component of LaSIP projects.

During December 1993, LaCEPT awarded 4 planning grants and 8 Campus Renewal Grants (CRGs) to 12 universities, totaling more than $800,000. The planning grants will support campus preparation leading to larger CRGs in subsequent years. The CRGs are directed toward the reform of teacher-preparation curricula in mathematics and/or science. A special research component housed at LSU will explore and illuminate the extent to which CRGs are efficacious.

During January 1994, LaCEPT held a statewide science conference which featured national representatives and attracted approximately 180 scientists, with each college and university represented.

C. CURRICULA

Major Achievement: The U.S. Department of Education funded a $900,000 Louisiana Mathematics and Science Framework Project, a collaborative partnership between the State Department of Education (SDE) and LaSIP, to produce effective mathematics and science curricula and assessment frameworks based on national standards.

The goal of the Curricula and Curricular Materials Panel is to assist the SDE in developing mathematics and science frameworks and state assessment instruments aligned with national standards, and to identify instructional materials that support reform curricula and assessment. Panel members decided to establish subpanels for mathematics and science. Each subpanel consists of approximately 30-40 members representing all educational stakeholders.

The subpanels employed national consultants to assist in broadening understanding and building consensus for curricular reform. Members examined the current state of affairs within Louisiana and determined how best to align state curricula and assessment with national reform. LaSIP and the SDE recognized the need for significant additional collaboration and funds to adequately address the state's curricular needs. With extensive statewide collaboration, a Framework Development Grant Proposal was submitted to the U.S. Department of Education by the SDE and LaSIP. The proposal included commitments of support from over 35 stakeholders, including state professional organization leaders, LaSIP panel chairs, university faculty, technology specialists, Eisenhower coordinators, Regional Service Center Directors, and business and industry representatives. The $900,000 grant proposal, funded in August 1993, exemplifies the broadening basis of systemic reform in Louisiana.

Both K-12 Mathematics Framework and grade-level handbooks are being developed. The drafts of the Mathematics Framework, including core content for 5-8 grades, are being examined by over 800 teachers, and will soon be reviewed by a Louisiana Equity Review Team, a National Validation Team, and a group of business and industry representatives. Thirty teachers across the state are piloting an 8th-Grade Mathematics Handbook, designed to assist the teacher in translating the NCTM Standards into classroom practice. During the spring of 1994, the core content for the K-4 grade levels will be developed; the 9-12 core content will be developed during the fall of 1994.

the science subpanel has completed writing the draft of the introduction to the framework and has established steering committees to oversee the writing of each section of the teacher handbooks for various grade-level ranges. A draft of the 6-8 science framework should be completed by June 1994.

Louisiana has a legislatively mandated state accountability program that requires the direct alignment of test items for students with the state curriculum. The current criterion-referenced tests are characterized by traditional multiple-choice formats that primarily include fact-recall questions in science and computational items in mathematics.

The SDE is exploring the feasibility of developing performance assessment tasks for the criterion-referenced tests. During the 1992-93 school year, over 750 students participated in a seventh-grade pilot mathematics performance assessment test, administered through the SDE. Further, approximately 600 eighth-grade students participated in a pilot performance assessment test developed by the state of Maryland. In both instances, the SDE engaged LaSIP teachers to administer and score tests, using these opportunities as expanded professional development experiences for state teachers.

While the state is making considerable progress toward reforming mathematics and science curricula, among the several challenges that remain are: (1) how to define curricula for 9-12 grade levels, considering the far-reaching implications of the graphing calculator on high school mathematics; (2) how to ensure equitable access to instructional materials for all students; and (3) how to appropriately and effectively integrate computers into the classroom.

D. TEACHER CERTIFICATION

Major Achievement: Three statewide conferences are being held to discuss needs, barriers, and choices involved in the modification of certification requirements.

Traditionally, Louisiana has had no middle school certification. Because of the critical shortage of mathematics and science teachers, panel members recognized that changes in certification requirements must occur in a manner that ensures an adequate supply of teachers who meet the new requirements. A problem lies in the fact that the authority for the various changes needed resides with different institutions. The SDE determines certification requirements, and each college or university develops its own preservice program.

During the first years of LaSIP, the Teacher Certification Panel reviewed certification policies and requirements from Louisiana and other states, NCATE and NSTA recommendations for certification, and reports from the Council of Chief State School Officers.

A steering committee was recently established to organize three statewide conferences to address certification issues at the K-4, 5-8, and 9-12 levels. The meetings featured the representation and advice of affected groups, including teachers.

The panel will continue to work with the BESE task force established by the state legislature to develop certification requirements for environmental science and with the committee established by BESE to revise Bulletin 746, which governs all certification requirements in Louisiana In cooperation with the SDE ad other policymakers, the panel plans to recommend standards-based modifications in certification requirements for K-12 mathematics and science teachers.

E. PROFESSIONAL PARTNERS

Major Achievement: A Professional Partners Handbook and Resource Guide has been developed to help direct the development of partnerships at the regional level.

Though the original intent of the partnership initiative was to coordinate efforts on a statewide basis, the panel and the LaSIP staff realized that partnerships have already developed throughout the state at local and regional levels. This trend accelerated with establishment of the 49 professional development projects. The Professional Partners Initiative was accordingly redesigned in the spring of 1992. The panel was dissolved and a half-time partnership consultant was employed and charged with the responsibility of developing a handbook to guide local schools and districts in developing their own partnership programs, and a resource database that could be used by both educators and the business community.

The professional partners initiative will continue to focus on regional, local, and statewide issues, working closely with the Information Dissemination Initiative to engage community and parental involvement in standards-based mathematics and science education. The consultant will build baseline data and collect follow-up data on professional partnership activities. In cooperation with other members of the LaSIP staff,the consultant will use the handbook and resource guide to help teachers appreciate the impact that carefully designed partnerships with the business community can have on classroom learning.

F. EDUCATIONAL TECHNOLOGY

Major Achievement: A statewide plan for educational technology has been developed, and manipulatives and grade-appropriate calculators have been placed directly in the hands of many teachers and students.

During the first year, national consultants were employed to help inform the Educational Technology Panel and other state leaders. Afterwards, the panel drafted a strategic plan for educational technology that emphasized the coordination of resources statewide. The plan identified pockets of excellence and of poverty in technology, and noted challenges to the dissemination of pacesetting technologies statewide.

Panelists recognized that additional resources would be needed to network the state. To further this goal, the BoR successfully submitted a $500,000 proposal (LaCHEN), funded by NSF, which now networks the state universities and colleges. Concurrently, the State Office of Telecommunications Management established LaNET, a statewide electronic network.

LaSIP's professional development initiative has emphasized the integration of technologies within the classroom. University faculty, stimulated by their involvement in LaSIP projects, are hosting graphing calculator workshops statewide. Some universities are requiring the use of graphing calculators in their classrooms. In addition, exemplary software programs that support national standards are demonstrated in various settings.

LaSIP recognizes that awareness of Internet's capabilities is paramount. As a consequence, LaSIP has organized Internet training sessions for personnel from the SDE and professional development projects. Over 40 individuals participated in training scheduled during December 1993. Additional sessions will be planned later.

The challenges for developing a comprehensive technology program in the state, though formidable, are recognized. Recently, Governor Edwards issued an executive order to develop a statewide technology plan by July 1994. Members of the LaSIP Educational Technology Panel will be a part of the task force.

During February 1994, LaSIP submitted a planning proposal in response to the NSF's Networking Infrastructure for Education (NIE)RFP. The purpose of the proposal is to design a plan which integrates the disparate statewide components of electronic networking.

G. INFORMATION DISSEMINATION

Major Achievement: Broadening awareness and understanding of the need for reform has been facilitated through newsletters, public service announcements and videos, statewide broadcasts, and a Tri-State Conference.

Six issues of NEXUS, LaSIP's newsletter, with an approximate circulation of 8,500 per issue, have been distributed to principals, teachers, university personnel, policymakers, and SSI, NSF, EDC personnel (see Appendix B). Further, a massproduced bumper sticker has been distributed statewide.

A one-hour live, statewide broadcast featuring Governor Edwin Edwards, me, as project director, and LaSIP Co-Project Director Raymond Arveson, was aired and then rebroadcast a week later because of intense viewer interest. The program included a live simulcast from Natchitoches in northern Louisiana, interactive responses to questions posed by the Governor to teachers assembled at 12 specially equipped sites around the state, a live studio audience, and callers posing questions to the panel.

With financial assistance from NSF and the Southwest Educational Development Laboratory, LaSIP hosted a Tri-State Conference, "Arkansas/Louisiana/Mississippi 2000 in Mathematics and Science Education," in New Orleans July 11-13, 1993. More than 500 individuals attended, including representatives from school systems; colleges and universities; business, industry, and labor; community and professional organizations; and the governmental sector of all three states.

LaSIP, Louisiana Public Broadcasting (LPB), and the Audubon Institute are planning to produce a 30-minute "habitat" television show for children ages 7-12, and 10 30-second institutional TV spots promoting conservation, science, and nature.

Governor Edwin Edwards honored recipients of 1994-95 LaSIP and LaCEPT awards on January 27, 1994, at a special press conference.

LaSIP will establish an internal computer network during 1994 with the capacity to include toll-free access for the dissemination of information regarding mathematics and science education. Once established, it is envisioned that this network will serve as a gateway between SSINET, SCINET, NSFNET, and educators throughout Louisiana.

H. REGIONAL AND LOCAL INSTITUTIONALIZATION OF REFORM

Major Achievement: After a careful review by out-of-state consultants that identified exemplary local programs and collaborations, reform efforts of the local Systemic Sites and Regional Service Centers are being restructured to more effectively coordinate and institutionalize reform at the local and regional levels.

LaSIP has established Local Systemic Sites (LSSs) at cooperating universities, and strengthened the mathematics and science K-12 outreach at the SDE's eight Regional Service Centers (RSCs). In FY 1993-94, 22 LSSs received $330,000, or $15,000 per site; RSCs received $240,000, or $30,000 per site. The intent of LaSIP has been that LSSs and RSCs in each region will integrate efforts to maximize the impact of reform at the community level. LaSIP has found pockets of excellence in activities of both the RSCs and the LSSs; interaction has varied greatly, however, between the RSCs and the LSSs in different regions throughout the state.

Concerned with improving the effectiveness of local and regional implementation, LaSIP employed an out-of-state review panel to evaluate the effectiveness of Local Systemic Sites. After reviewing documentation, conducting personal interviews with Systemic Site PIs, and discussing local and regional efforts with the LaSIP staff, the panel recommended an RFP process to effect a reduction in the number of administrative centers and sites to eight, to coincide with the eight geographical regions currently defined by the RSCs. The panel further recommended that a full-time director be employed at each site. The panel's recommendations will be presented to the LaSIP Council at its January meeting.

I. EVALUATION

Assessment of the extent to which in-state directions and practices reflect the requirements of national reform has been the overarching consideration shaping strategies for evaluation. Four approaches have been followed: (l) recognized out-of-state consultants have frequently been engaged to conduct evaluations and to broaden perspectives of in-state reformers; (2) maintaining competence and currency of the professional staff has remained an essential priority; (3) change agents for reform have been strategically placed in schools, localities, and regions; and (4) an overall plan of evaluation has been formulated to calibrate success in achieving general and specific goals.

The classic separation of formative from summative evaluation has only limited meaning when applied to LaSIP. Preliminary summative judgments are continually reshaping goals and expectations. Staff reassessments and review by out-of-state consultants have constituted consequential ongoing evaluations, both formatively and summatively; these have helped modify directions of developing programs based on emerging needs and opportunities. Data are collected and collated based on indicators identified for LaSIP's overall systemic goals, along with indicators for respective initiatives and programs.

The evaluation model, inclusive of dynamic goals, strategies, priorities, and programs, has necessarily remained adaptive itself. Ways of collecting and interpreting data continue to evolve as the scope, meaning, and implications of standards-based systemic reform are more fully understood.

V. SUMMARY AND CONCLUSION

Perspectives of the key stakeholders in Louisiana regarding systemic change and modes of implementation have deepened considerably during the last three years. The breadth and depth of vision has been sharpened by the evolving science Benchmarks and Standards, the NCTM Professional Standards, the greatly increased emphasis on assessment and diversity issues, the continuing revolution in interactive technology, and the growing realization that the still developing hand-held graphing calculator (and/or computer) will eventually change 9-12 mathematics and science as much as the four-function calculator will change K-8 mathematics.

It is roughly estimated that the ages of technology and information require a 90 percent change both in K-12 mathematics content and classroom practice, and almost as much change in science. This formidable challenge is also a golden opportunity. Modern transformations are making most of traditional school mathematics and science irrelevant to life in the 21st century. It has become imperative to help redirect student learning away from paper-and-pencil drill and rote memorization toward hands-on problem solving, communicating, reasoning, and connecting, which are all pervasive themes of the Benchmarks and the NCTM Standards.

At this stage, LaSIP assesses the efficacy of its efforts in relation to the magnitude of change required. Early results have been encouraging. The professional development program, the core of LaSIP, has exceeded expectations in the wide replicability of, and improvement on, the original NSF-supported models. The primary focus on teachers of grades 4-8 and their students was wisely chosen. Initial general skepticism about a new program with statewide ambition has largely been overcome by the enthusiasm and dedication of teachers, faculty, policymakers, and other stakeholders across the state. The NSF and matching state funds have been expended as originally planned. There have been no personnel turnovers on LaSIP's carefully selected professional staff, now identified statewide as reform leaders. And, notably, there has been no recorded dissent on any major LaSIP funding issue voted on by the BoR, the BESE, or the LaSIP Council. Both within and outside Louisiana, the LaSIP staff has been encouraged by enthusiastic comments about the LaSIP program. Out-of-state visitors and consultants, including those with ties to NSF, have generally concluded that the program is achieving its goals in impressive ways.

Other developments have also been particularly gratis. Across the state there are now inspired teacher-leaders, other school personnel, and university faculty who have become fully committed to the vision of standards-based reform. They are leading many others to the belief that the massive educational changes needed to equip Louisianians for life in the 21st century are indeed possible. Highly effective and unprecedented relationships have been forged between members of the institutions of higher education (IHEs) and local education agencies (LEAs). A vision has evolved among IHE personnel (mathematical, scientific, and educational) regarding the reform of teacher preparation programs that would have been unthinkable two years ago. Such faculty involvement and attitudes have led to the development of, and NSF funding for, the Collaborative for Excellence in the Preparation of Teachers and an evolving plan by chemistry faculty to submit a statewide proposal to NSF for the reform of chemistry curricula.

While considerable work remains to be done, the accomplishments of LaSIP have been notable. Furthermore, LaSIP has helped to alter the Louisiana landscape in a manner that enhances prospects for the longer-range achievement of standards-based systemic reform.

[Due to the high cost of printing, the appendixes A-C are retrained in the files of the committee.]

The CHAIRMAN. That is certainly a hopeful commentary in terms of what can be done in our society in the areas of education reform. It is an interesting fact that we will be doing Goals 2000, not that goals, obviously, will do all the things that we hope it will do, but it is very closely aligned to take advantage of many of the points you make.

I will just take a couple of minutes because of the time constraints, but in looking over the program, as I understand, you have three substantive elements of reform, including professional development, which is obviously the teachers, and pre-service teacher preparation—I am not quite sure what that is.

Mr. DAVIDSON. That is primarily revisions in the college-level courses and curricula that help prepare future teachers.

The CHAIRMAN. So that is again for the teachers?

Mr. DAVIDSON. For the teachers of the future, yes.

The CHAIRMAN. OK. And then curricula and assessment—are these content standards in terms of the curricula; is that what we are talking about?

Mr. DAVIDSON. That is correct. This is a special program funded by the Department of Education that is designed to establish statewide mathematics and science curricula frameworks.

The CHAIRMAN. And you are doing these assessments in a different way than usual—I mean, are you doing it with portfolios and other kinds of presentations, rather than just the punch-through kinds of programs.

Mr. DAVIDSON. That is correct. In every dimension, we are guided by the national standards and the national movement toward authentic assessment.

The CHAIRMAN. The thing that we are always asked about is whether these content standards and the assessments can really be developed. What you are saying is that Louisiana has been able to do it in these areas, with successful results. Is what I am hearing from you?

Mr. DAVIDSON. The highest priority since the beginning of the program has been professional development. The development of the content standards is a more recent phenomenon. The project was funded within the last 6 or 7 months so the results are not entirely in.

The CHAIRMAN. OK. Finally, the thing that we spent a lot of time on—and it almost broke down the whole negotiation—was the opportunity-to-learn standards, and can we evaluate outputs if we do not evaluate inputs. In my part of the country, in Boston, there are schools that are 60 or 70 years old, with plaster falling off the ceilings, and inadequate physical facilities. Boston Latin School, for example, is 35-40 percent AFDC children, 35 percent of them black, about 30 percent white, and 30 percent Hispanic and Asian, and 98 percent of them are getting into college. But putting that aside, I think the opportunity-to-learn standards are important, and we have the most difficulty in terms of the ideological politics of it.

Have you formed an impression about how that fits into these other criteria which you have referenced here, too?

Mr. DAVIDSON. The impression I have is that our work is only beginning and that we have to cooperate with other sources of funding and with other avenues in order to make certain that we bring to bear a variety of remedies to a very complicated problem. We are now actively involved in trying to cooperate with Title I and Chapter 2, and bring the NSF and Eisenhower moneys together, to have the kind of an impact to make sure that the input as well as the output are there.

The CHAIRMAN. That is good. And on flexibility, have you had some flexibility in terms of bringing those programs together at the local level, or has the rigidity of Federal regulations, even NSF regulations, local and State, impeded you, or have they given you flexibility to carry through the consistency of the approach in terms of math and science, and give you more flexibility in dealing with resources at the local level?

Mr. DAVIDSON. We are assisted considerably by the growing flexibility at the Federal level. There is cooperation between NSF and other Federal agencies, and the message that we are getting is that we should have these revised standards at the local and State levels.

The CHAIRMAN. Senator Mikulski.

Senator MIKULSKI. Thank you very much.

A question for you, Dr. Davidson, and then for Dr. Schmitt and Dr. Bush. Dr. Davidson, this is a stunning set of accomplishments. I have just perused this, but I intend to take this testimony home and really review it thoroughly. I would like to congratulate you and the people of Louisiana for really using Federal dollars to accomplish exactly what we had hoped to when we funded the project.

My question, Dr. Davidson, is would Louisiana have done this without the National Science Foundation funding. What was so important about the National Science Foundation funding that then launched Louisiana in this bold and transformational endeavor?

Mr. DAVIDSON. Well, that is the easiest question I could be asked, because the answer is absolutely not. There is some magic about a national agency like the National Science Foundation saying here is $10 million and a program we have never funded this way before, if the State will put up a match and move things aggressively forward. That has really been the catalyst for everything that we have done. I would like to think we would have done it without NSF, but I know that would not have happened.

Senator MIKULSKI. Just a follow-up question, Dr. Davidson. Would the possibility of a $10 million grant to the Louisiana school system then enable talented administrators like yourself and others to say, "If we are going to go for it—it is almost like going for a Malcolm Baldridge award—we have to get our act together". Does the process of getting your act together to get the grant causes everyone to give up pet turfs, pet peeves, pet theories, pet union rules, and so on, and then try to end up being teachers' pets, to really go for the gold?

Mr. DAVIDSON. I believe that those are the most important changes which occur are those changes in moods and behavior that lay the foundation for future policies, and those kinds of collaborations started before the proposal was submitted to NSF, and they have continued more aggressively since the project has been underway.

Senator MIKULSKI. Right now, one of our most difficult areas, of course, are the urban areas. It was Dr. Luther Williams who also said that in addition to statewide, you needed a special focus on the urban initiative. Have you applied for an urban initiative? Would that have been able to leverage the Louisiana advancements?

Mr. DAVIDSON. There are some areas, obviously, where the problem is of greater magnitude than others, and certainly the rural areas and the urban areas so classify. If I were not here today, I would be attending a multiState conference to develop a rural initiative proposal for the Delta region. And later on this week, I am going to be attending an urban initiative proposal which will bring in representatives from New Orleans.

I think the resources that those areas need should be appended to, rather than a part of, the statewide systemic initiatives program.

Senator MIKULSKI. So the statewide initiative program is important, and at the same time, there should be additional programs that focus on rural areas, like the Delta, and then you have the New Orleans area. But the statewide reform is there for both the urban and rural areas to build on, is that it? Are urban and rural programs in addition to, not in lieu of a statewide initiative?

Mr. DAVIDSON. I think these can be considered as major components and centers within the statewide effort.

Senator MIKULSKI. And Dr. Davidson, for example, you talked about the Delta, which will probably be a multiState area. Do you feel that if the State is sluggish in moving on a State grant, it means a rural consortium or a city could go for it on its own, and not wait around?

Mr. DAVIDSON. That is my understanding, yes.

Senator MIKULSKI. That is very good.

I know that we have a vote coming up, and I would like to ask one question of Dr. Schmitt and Dr. Bush.

The CHAIRMAN. Would the Senator yield on this?

Senator MIKULSKI. Yes.

The CHAIRMAN. Luther Williams, who is head of education at NSF, is here today. Would you like to stand? No, he does not want to stand. But for the record, we want to commend him for what he has been doing.

Senator MIKULSKI. Yes.

Quoting from BusinessWeek: "For 50 years, the powerhouse team of the Federal Government, universities, and corporate labs have awed the world with U.S. research universities being number one and Americans dominating the Nobel Prize. But now, both the Federal Government and research labs are rethinking their role." That triad of corporate research labs, the university base, and the Federal Government is what has been so stunning in the last 50 years.

Now I understand that corporate labs are cutting back dramatically, it is estimated by about 15 percent, and going from long-term pursuits in addition to value-added product development to more short-term because of the drives of Wall Street.

The Federal Government is facing the same problems that the corporate labs have, which is a shortage of disposable capital. How would you recommend, then, that we spend our money, moving on accomplishing national goals—and Dr. Schmitt, I thank you so much for your testimony, and I think you have now read enough about what I have said and heard me say that you probably want to revise that January 1994 article in Physics Today.

Mr. SCHMITT. I think that was consistent with what you say, Senator, totally.

Senator MIKULSKI [continuing]. But my question is that we do not have all the money in the world, and in BusinessWeek they are asking could we now afford the transistor?" I think the question is not "can we afford the transistor", but "what can we afford" to help this triad continue. What then should be the role of the Federal Government; to help the corporate labs, which value-add for product development as well as work to advance their own long-term goals through tax credits or whatever. The public is asking not so much will you produce a bifocal that can be used as a substitute for sunglasses—something very precise—or how you do not cut yourself with a new razor. What would be your recommendations?

Mr. SCHMITT. Do you want both of us to answer that?

Senator MIKULSKI. Yes.

Mr. SCHMITT. I think that you characterize the situation today correctly, Senator. If you look back in history, it has been the pioneering discoveries—the transistor, the microprocessor, the laser, the fiberoptics, the biotechnology ventures—that have launched entirely new industries that have created jobs. One of our concerns for the future is to create jobs.

The United States in the past several decades fell behind not in the pioneering discoveries—as a matter of fact, the U.s. made most of these pioneering discoveries and was the first to launch industries—but we were failing in the follow-up to that, and that is where Japan beat us.

Today, the U.S. has learned how to do that, or relearned, I should say. So I think the competitiveness issue, the quality, low cost, productivity issues have been addressed by industry. At the same time, however, because the growth rate of industrial R and D dropped in the mid-1980's, this pioneering work has been squeezed out of corporate laboratories, as you State. I believe that is a serious national problem, and I believe that the Federal Government has to accept that as a serious national priority, to make sure that we reinvigorate, restimulate the pioneering work in our corporate laboratories and protect it in our research universities, which have been the other source of these.

So I would say that from a strategic point of view, that itself, as Dr. Bush said a moment ago, becomes a primary, very high-priority, strategic field for the Federal Government.

Senator MIKULSKI. Dr. Bush—and the second bell has run, so I have to go vote on a Republican alternative on the budget, and I have to choose between you and that—but would you give us your thoughts, briefly?

Mr. BUSH. A couple of comments. One, the information you have from BusinessWeek is, of course, accurate in aggregate. But if you look at industry by industry, our corporate laboratories have been growing at about 8 percent a year, steadily. So it is not that this is a global problem for American industry. It is a very specific problem for what were the technology-led industries of America.

I used to work for Roland, so I know a little bit about the kind of laboratory that he operated, and it was a great laboratory. We do not operate a laboratory like that. We operate some very good ones, and I would invite you to come to our Gaithersburg laboratory sometime to see that.

Senator MIKULSKI. I will, I will.

Mr. BUSH. Good. But what we do, our stock and trade, is matching knowledge with getting products out, and we are relying on the National Science Foundation to provide us with the upstream, fundamental work that will enable us to do that. However, as I said in my testimony, I do not think one bit of fundamental work is as valuable as another bit in getting commercial results. We have to have a means of sorting out and prioritizing, and I suggest some ways.

Senator MIKULSKI. Well, it is regrettable that we are in the midst of a vote. When we scheduled this hearing, we did not know that the budget was going to be on the floor. So your position is that through the National Science Foundation, or our other great Federal labs, doing basic research, there are many private sector labs who then value-add for the specific product development. And that further, many companies, and particularly small companies, could have never done that basic research on their own. We become in some ways the risk capital, the venture capitalist, in science and research; is that it?

Mr. BUSH. In biotechnology, for example, that certainly has been true. I had the opportunity the other day to meet a man who heads a small company near Detroit, who depends on one of the NSF's cooperative centers for his basic research. He has a $50,000 budget for translating basic research—for getting basic research, he invests that in that center. As I tried to mention, I think those centers are very interesting and valuable experiments.

Senator MIKULSKI. Well, I would like to thank you both, and Dr. Schmitt, I bet you did run a great laboratory, and I think you still run a great laboratory of ideas. Dr. Bush, Dr. Davidson—again, our special congratulations to the people of Louisiana.

We are going to be working for several months on the authorization, or at least probably between now and the 4th of July—that is our definition of several months. We will look forward to further conversations with you. We will include everyone's complete testimony and any additional submissions for the record.

[Additional statements and material submitted for the record follows:]

Testimony Before the
Labor and Human Resources Committee
United States Senate
Roland W. Schmitt
President Emeritus-Rensselaer Polytechnic Institute
Senior Vice President(Retired) - Science & Technology - GE
March 23, 1994

Thank you for the opportunity to testify on the important issue before this Committee: the authorization bill for the National Science Foundation. Although I am a member of the National Science Board, I am not speaking in that capacity today. This is a personal appearance at the invitation of the Committee because of views that I've expressed recently in published articles.

The role of the National Science Foundation in pursuing national goals is the subject of considerable discussion. The scientific community by-and-large believes that the NSF's traditional role of supporting investigator-initiated, basic academic research should be preserved above all else while the political community and much of the public believes that it should devote most of its effort to addressing national goals. My position is simple. There is no fundamental conflict between these goals. Along with my oral testimony this morning, I would like to submit the essence of two papers and talks that I have given in the past on this issue. You will see that these messages, addressed largely to the scientific community, have argued to them that there is no conflict if that community recognizes that problems and issues encountered in practice are just as rich a source of inspiration for pioneering research as is the untrammeled curiosity of scientists. This morning I would like to address political concerns and suggest that national interests are well served by the pioneering, academic research typically supported by NSF.

There are fundamentally four rationales for the public support of basic, pioneering research: 1) the desire to answer enduring, fundamental questions about the universe, nature and man; 2) the appeal of a frontier to be conquered - a uniquely American rationale, rooted in our history; 3) the usefulness of science; and 4) the political appeal of many scientific projects and programs. Much of the current misunderstanding comes from the simple fact that scientists and politicians have exactly reversed priorities among these four rationales. The academic scientist, left to his own taste, would usually prefer being an individual investigator, doing basic research in a disciplinary field shared with his peers, driven by his own curiosity and hopeful of long term impact on man's understanding of nature or on new frontiers. Those who pay for the research prefer strategically-driven, applied work by interdisciplinary teams with near term impact on industrial, social or political problems. My position is that the dichotomy is false; both can have their way.

How do we reconcile these seemingly disparate interests?

First, when you go into laboratories where the research is actually done, most of these distinctions lose their meaning. Nature simply doesn't reveal its secrets preferentially to one or the other. When I ran a corporate laboratory - a very successful one in both the new products and businesses it generated for the corporation and in the honors and distinctions won by its scientists (including a Nobel Prize) - I would challenge visitors who wanted to strongly delineate basic and applied research: visit a laboratory, observe what the scientists were doing and from that alone judge whether the research was basic or applied. It's hard to do. Nature doesn't care what the labels and motivations are, only how good and clever you are in asking the right questions, devising the right experiments, inventing the right ideas, making the right calculations.

The basic scientist, the academic researcher is good at ferreting out secrets of nature that are both interesting and useful. The scientist approaches questions by experimentation, by understanding and by discovering. The pragmatist approaches problems by trial and error, by inventing and by improvising. We need both. In the 16th Century, Francis Bacon said, "axioms rightly discovered and established supply practice with its instruments, not one by one, but in clusters, drawing after them trains and troops of works." No one has expressed the importance of basic understanding better than that.

Irving Langmuir, the first U.S. industrial chemist to win a Nobel Prize, is a wonderful example. Early in his career at General Electric, the research director asked Langmuir to find a way to keep light bulbs from turning black. Langmuir, being a scientist, did not just start building bulbs of different sizes and shapes or filaments of different configurations, an approach that would have been the obvious, strightforward approach and one more easily understood by his industrial bosses. Instead, he tried to understand what physical and chemical phenomena were going on in the bulb. Several times, he told the Lab Director that he wasn't sure whether or not he was on the right track. The director reassured Langmuir, telling him to continue in the way he thought best to solve the problem. In the end, Langmuir not only learned enough about nature to solve the problem in a simple way that he would never have found by the straightforward approach. And, in the process, he launched the line of research that led to modern surface chemistry and won him a Nobel Prize.

The lesson is simple: you may point to the problems you'd like scientists to address, but then leave them alone. Trying to tell them what not to do is like telling a salesman to quit calling on people who aren't going to buy the product. It won't improve the salesman's productivity!

In practice, the right way to harmonize the divergent interests of politicians and scientists is to let agency heads and administrators worry about the purposes and let the scientists worry about getting ideas and doing experiments.

Broad goals should flow from top down. What to do about them should be decided at the "bottom". Let scientists be scientists. They've produced in the past; they will in the future. Don't try too hard to mastermind the system. We need constantly to remind ourselves of our fallibility: Tom Watson, the man who eventually launched IBM into the computer industry said, in 1943, "I think there is a world market for about five computers." In fact, Fortune Magazine (April 4, 1994) recently reported that "In 1991 companies for the first time spent more on computing and communications gear ... than on industrial, mining, farm and construction machines." And autos now have $675 worth of steel and $782 worth of microelectronics in them (same source)! The history of the emergence and growth of microelectronics is filled with Nobel-Prize winning scientific discoveries that launched the subsequent industry-creating, job-creating, life-enhancing revolution.

And this brings me to why the NSF is so important in today's world. To create new jobs, one must discover and meet new needs, create new markets, introduce new kinds of products, and launch new industries rather than focus solely on refining products and improving the productivity of existing markets and industries. Science and technology are the most important sources of such new industries through pioneering discoveries and inventions. Science and technology not only creates new wealth; they alone create new sources of wealth.

Historically, the U.S. has been both the dominant source of breakthroughs in science and technology and, usually, the first to commercialize them. A nation, such as ours, that needs to create new jobs for a growing population of workers and for those displaced from mature industries ought to be especially supportive of pioneering research.

The questions are: where do these pioneering innovations come from and how do we ensure a continuing stream of them in the future? The first question is easy to answer. The most important breakthroughs in recent history have originated from either corporate laboratories, such as those of AT&T, IBM, General Electric, Corning, DuPont, or Xerox, or from research universities, such as University of Pennsylvania, Stanford. the University of Alabama at Huntsville, MIT, the State University of New York at Stonybrook, and many more. These breakthroughs include transistors, integrated circuits, microprocessors, computers, lasers, fiber optics, object oriented programming, graphical interfaces, CAT scanning, magnetic resonance imaging, RISC architecture, recombinant DNA, monoclonal antibodies and many more.

Today, however, both corporate laboratories and academic institutions, are troubled.

In the 1980's, corporate laboratories, responding to the demands of financial markets and the realization that Japanese companies were beating us in near-term, commercial R&D, reduced their time horizons. As a result, these laboratories became less venturesome. In addition, there was a sharp slowdown in the growth of industrial R&D in the second half of the 1980's.

During '80's, research in universities also became increasingly troubled, despite the fact that there was significant growth in financial support for academic research. The federal share of this support descreased significantly, plummeting from 68% in 1980 to 58% in 1991. Support of academic research by industry and by the academic institutions themselves grew more rapidly than federal support but these sources of funding are strained, today. Thus, NSF, as one of the principal sources of funding for pioneering, academic research is becoming more and more vital to our nation if we are to continue creating new, job-creating industries in the future.

The NSF is a superb instrument for serving national purposes. It has been so in the past; it can be so in the future. With the leadership you have shown in searching for a harmonization of national goals with the pioneering scientific spirit, and with the new NSF leadership, I am sure that NSF will play a growing role in fullfilling these national goals.

PUBLIC SUPPORT OF SCIENCE: SEARCHING FOR HARMONY

Since the cold war ended, scientists and politicians seem increasingly at odds. Scientists need to address social concerns more squarely in their work.

Roland W. Schmitt

My subject is the rationale for public support of science in the post cold war era. The first question is, Whose rationale? Congressman George Brown's or Senator Barbara Mikulski's or President Bill Clinton's or Phil Anderson's or Leon Lederman's? Everyone seems to be singing different tunes, and it is hard to hear any harmony in their voices. And yet with the profound changes in the forces that have driven our Federal science and technology policies, it is now more important than ever to find that harmony.

The rhetoric of today seems to signal a growing disagreement between the politicians and the scientific community. But I believe that schism is, to paraphrase Dorothy Parker, on the surface very profound but deep down quite shallow. I'd like to dig a little to see if we can find a harmony that is not just a compromise but rather is based on a valid synergy of interests.

Serendipity versus strategy

Let's start by looking at two representatives of the public, both of whom are influential in the life of US science today: Congressman Brown and Senator Mikulski.

Brown is urging a strategic approach to funding science, in place of reliance on serendipity—the approach he feels has characterized the past. As he puts it, "New directions must move us from the myriad serendipitous paths of where we are capable of going, to the strategic paths where we must go if the planet and its increasing population are to survive."

Mikulski is also an advocate of a "strategic focus on basic research." She warns scientists not to "shroud curiosity-driven activities under the rubric of strategic activities." She warns that if the National Science Foundation can't set "specific performance milestones," then some of its funding ought to go to other agencies that can set such milestones.

Now, you may be thinking, With friends like these, who needs enemies? Serendipity and curiosity have been the mantras of scientists seeking more funding for basic research. Indeed, the American Chemical Society has titled a glossy four color booklet promoting the need for more pure research "Science and Serendipity."

Physicists, too, see serendipity and curiosity as virtues, and so it is disturbing to hear Brown and Mikulski describe them as vices. That emphasis on "strategy" also sounds worrisome, more appropriate for the battlefield or the boardroom than for the scientific laboratory. We may begin to wonder whether we have reached a time in which William Proxmire, the former Democratic Senator from Wisconsin, and his Golden Fleece Awards look like the good old days!

Reasons for science support

Searching for harmony between the science community and the politicians may seem like a stretch, but let's try. Let's start by looking at some of the fundamentals of why the public supports science.

I believe the reasons are at least fourfold. First is the desire to answer enduring, fundamental questions about the universe, nature and humankind, that is, the search for truth; second is the lure of a frontier to be conquered, the desire to be pioneers in keeping with our American ancestry; third is the utility of science, a feature that distinguishes the search for truth; and fourth is the immediate political appeal of many scientific projects and programs, having to do with the direct benefits to be obtained from executing them.

Let's look at these briefly, one by one.

Search for truth. First is the search for understanding, for underlying truths. The public does have an interest in uncovering truths about the universe: What are we made of? Where did we come from? Where are we going? At least since the Babylonians and Ionian Greeks, thousands of years ago, people have undertaken the quest for truth with support from the public. But if truth and understanding are the only motives, why support science any more lavishly than we support the humanities or the arts, which also provide a window on truth? Total funds available annually for the National Endowment for the Humanities and the National Endow-

Roland W. Schmitt is chairman of the Governing Board of the American Institute of Physics. He is president emeritus of Rensselaer Polytechnic Institute and Senior Vice President (retired), Science & Technology, General Electric.

Congressman Sherwood Louis Boehlert, the ranking Republican on the House science subcommittee, was a leader of House opposition to the SSC, which he considered too expensive [illegible] to promote science. Since 1983 Boehlert has represented Utica, New York.

ment for the Arts from the Federal government amount to a little over $100 million, about four thousandths of Federal expenditures on science and technology and less than 3% of Federal expenditures on basic research. One must conclude that much more is at stake than the search for truth and understanding.

The constricted frontier. The second rationale for public support of science in the US is that it is a pioneering activity. The pioneering urge is distinctly American, but only in the past half century has it been firmly linked to public support of research. The person most responsible for making the linkage was Vannevar Bush. At the end of World War II, Bush issued his famous report *Science—the Endless Frontier*. In that simple title he made explicit that America's new frontier was science and technology. Bush's personal view, however, was that pioneering research included more than just the search for knowledge for its own sake. It also included "basic technology" or "engineering research," activities that generate "knowledge in order to do, not for knowing alone." He liked to illustrate this with the Wright brothers, who, in order to invent the wings for their airplane, first carried out engineering research using wind tunnels.

To encompass both scientific research and engineering research, Bush proposed a single Federal agency with responsibility across the whole scope of the science and technology frontier. Unfortunately, most of Bush's collaborators in writing *Science—the Endless Frontier* were professors who were not necessarily pioneers. When Bush tried out his ideas about basic technology and the Wright brothers on them, they haughtily told him that they "did not think a couple of bicycle mechanics working on a flying machine would . . . be doing research."[1]

So the consensus at the time was to keep the ennobling pursuit of knowledge free from the taint of the Wright brothers' bicycle shop. Rather than a single Federal agency with responsibility for the whole frontier, as Bush had wanted, there emerged a proposal for an agency responsible only for the science end—what became the National Science Foundation. And the American scientific community, though not the public, adopted this narrowed vision of the frontier. Since then, we in science have fallen into an even narrower self-image that equates the frontier with "curiosity driven" research alone.

General utility. The third reason the public supports science has to do with its general utility—that is, the power of science to change the world. This goes back at least to the 16th century, when Francis Bacon argued explicitly that the support of science would be useful to society. In Bacon's words, "axioms rightly discovered and established supply practice with its instruments, not one by one, but in clusters, drawing after them trains and troops of works." His view has been abundantly confirmed; nobody disputes it today. The knowledgeable critics of science, such as Brown and Mikulski, argue not about the utility of science but about how to harvest that utility. They recognize that science is useful, and they recognize that to be useful it must be done by talented scientists, not by political appointees. But they would like to influence what those talented scientists do.

Mikulski may have harsh words for curiosity-driven activities, but she has no problem with efforts to "bolster the research enterprise while creating jobs in the construction and manufacturing sector."

Special benefits. This brings us to our fourth and most politically appealing reason: The direct benefits science projects and programs bring to specific constituencies.

You may not like this factor and may agree with I. I. Rabi, who once said, "In science we can't let some guy from Podunk have the same vote as Fermi." But in fact those guys from Podunk do have the same vote as a Nobel laureate from Chicago in deciding whether or not to support science. And the specific appeal of a project to voters—is a legitimate reason for the public to support science.

Right now, the Superconducting Super Collider is the most interesting case in point. The research to have been done with the machine addressed questions that Western culture has been asking for over two millennia: What is the fundamental nature of matter and how did it originate? Moreover, the people who wanted to build it regarded themselves and presented themselves as pioneers and explorers.

In the end, however, the SSC stood or fell not because of its potential contributions to our understanding of the first picosecond of the big bang or the deepest structure of matter, but because of the political clout of the Texas Congressional delegation and its allies. That clout had been seriously weakened in the last few years with the ouster of Jim Wright as Speaker of the House, with the defeat of George Bush as President, and with the departure of Senator Lloyd Bentsen, who had been chairman of the Senate Finance Committee, to the Treasury Department. Moreover, Texas now has two minority-party senators. So the SSC has been lost. The vote of that "guy from Podunk"—New York Congressman Sherwood Boehlert,[2] if you like—does outweigh that of a Nobel laureate, Leon Lederman; physicists haven't learned that

Rabi got this one wrong! Meanwhile the space station survives, probably because it is believed to be pioneering by the people from Podunk and because it keeps the Podunkers employed in the aerospace industry.

Inverted priorities

The order of these four motives for government support of research—understanding, pioneering, utility and specific political attractiveness—is the order of increasing appeal to politicians and administrators. Yet it is the order of decreasing appeal to most of the researchers who receive public support.

For scientists, understanding is at the top. The greatest heroes of science are the likes of Darwin and Einstein—individuals who brought new truth to the world. Second on the list is pioneering. Scientists like the idea that they are the frontier persons of today, although they have forgotten Vannevar Bush's broader vision of it. Utility, important to many scientists, nevertheless typically comes in third. And of course special benefits to political constituents come in last. Scientists do not reject this last factor, but most find it either a necessary evil or a slight embarrassment.

For politicians, the order is exactly reversed. Political attractiveness comes out on top. Utility follows close behind. Pioneering comes third, and understanding comes last.

During the decades since Bush's report, this dichotomy was reconciled by the belief that satisfying the first two rationales—answering basic questions and pushing at frontiers—would act more or less automatically to produce the right outcome for the second two rationales—utility and political value. And that has been partly true. But today too many things have gone wrong. Americans have dominated Nobel prizes while many of our industries have lost their competitiveness. Our nation is faced with too many urgent problems—disease, infrastructural decay, environmental blight, violent crime, drugs, homelessness—that have not yet found solutions; nor have scientists satisfied political interest through attacking basic questions or doing pioneering research.

Meanwhile we scientists insist on a rhetoric that talks about curiosity driven research. We tend to assume that our own enthusiasm for what we do is shared by the public. But by and large it isn't. Instead, much of the public shares the view of the former Dutch Queen Juliana, who once exclaimed, "I don't understand computers. Why, I don't even understand the people who understand computers!"

Searching for harmony

So what do we do to reconcile these different priorities, to find a harmony that both parties hear? How do we define a new compact that will reinvigorate the scientific enterprise and all of the remarkable benefits it brings to our nation?

A recent report of the Committee on Science, Engineering and Public Policy of the National Academies of Science and Engineering suggests that the new compact should be based on goals of having the US "be among the world leaders in all major areas of science and of maintaining clear leadership in some major areas of science." While I believe that this is an important suggestion that has launched constructive debate within the scientific community, it is essentially a supply-side policy, an inward looking policy; it only tells us how to set priorities within the scientific enterprise. And so, even if we agree on this particular suggestion, we will still not have responded adequately to public concerns.

So what do we do to find this new compact that

Leon Lederman, a former director of Fermilab, was a leading proponent of the Superconducting Super Collider. A Nobel prize winner recognized for several major contributions to particle physics, Lederman also has spearheaded science education reform efforts in Illinois, his adoptive state. He is currently professor of science at the Illinois Institute of Technology in Chicago.

everyone wants? To begin with, our four elements—understanding, pioneering, applications and local benefits—are not mutually exclusive. They have much common ground, much synergy, and it is precisely in this fact that we must find solutions. It is not just a matter of educating the public and the politicians about us. It is also a matter of educating ourselves about them and their needs.

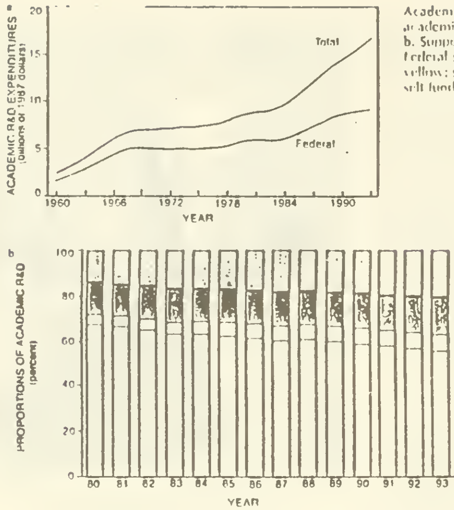
Let's begin with several observations of the scene today that are related to science and technology policy.

▷ American industry has lost competitiveness in a number of markets. This theme dominated policy in the 1980s, and we have just begun to turn things around.

▷ About 5% of our gross national product has been in defense, but with the end of the cold war, this will decrease to something under 3% before the end of the decade. Because our economy grows a good deal more than 2% per year, this shift should be easily accommodated from a macroeconomic perspective. But, the industrial and commercial activity that will replace defense will probably be less technologically intensive, requiring a lower rate of investment in R&D than did defense.

▷ We need to create high-quality jobs—to accommodate population growth and to offset those jobs lost in established industries—in industries that are becoming more productive and competitive.

▷ We need to make better and more rapid progress in



Academic R&D expenditures. a. Real total and Federal academic R&D expenditures from 1960 to the present. b. Support of academic R&D from 1980 to the present. Federal support is shown in blue; industrial support in yellow; state, local and other support in orange, and self funded in green. (Source: National Science Foundation.)

solving many economic and social problems, notably in the areas of the environment, infrastructure, health, energy, commerce and crime.

R&D—specific issues

In addition to these technologically relevant national issues, there are also a number of issues specific to the R&D system. Among the important ones are:

▷ Decline in industrial research. The growth rate of industrial R&D dropped significantly in the mid 1980s; since then, there also has been a shift of industrial R&D away from the pioneering work that has given rise to new industries, new businesses and new product lines.

▷ Defense R&D conversion. About one-third of the total US R&D expenditures, which amount to about $150 billion annually, have been devoted to defense. Today, about 60% of the Federal government's yearly R&D expenditures of $75 billion goes to defense. The administration has said it wants to change the Federal ratio to 50/50 by 1998, which means about $7.5 billion should be shifted from defense to civilian R&D. The programs in place today—the Technology Reinvestment Program, CRADAS, the Advanced Technology Program, the Manufacturing Technology Centers—look like they will be funded at about $2.5 billion within the next few years. This leaves a $5 billion gap that we simply can't let become a $5 billion cut!

▷ Federal support for universities. While academic R&D grew significantly during the 1980s, the Federal portion of that support shrank. Academic institutions provided rapidly growing support for their own R&D, but this trend cannot continue in light of the financial problems that most research universities are encountering (see charts, upper left).

▷ Imperiled innovation. Because of the trends in both industrial and academic R&D, the nation's traditional strength in the kind of pioneering R&D that has led to new industries and job creation is threatened.

Thinking nationally

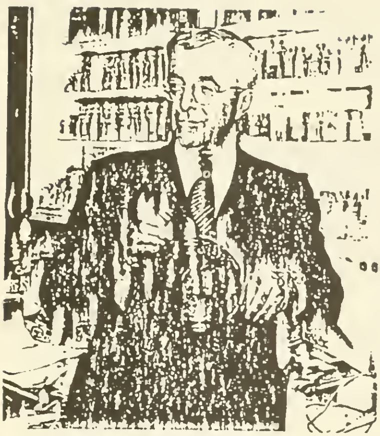
These problems of the national R&D system are serious. But if we are going to solve them, we need to make our solutions also be an important part of solving the nation's problems; we need to think that way, and we need to act that way.

As soon as one says this, however, people immediately think one is saying that basic scientists, exploratory scientists, pioneering scientists must append applied research and technology transfer to their curiosity-driven explorations. But I don't believe that is the answer. There is a better approach.

The answer, I believe, is to accept the responsibility of addressing issues of national importance, issues of strategic importance, issues of political importance, but to respond not by trying to do things we don't do well but by doing what we do do well—that is, pioneering, exploratory, basic work that is inspired by these tough problems. In the course of responding this way, we will enrich our own world; our curiosity will have an even broader, even more challenging terrain to explore.

Let's go back for a moment and look at what Congressman Brown and Senator Mikulski are really saying.

They are not saying that politicians should be looking over the shoulders of scientists and telling them what to do. They are merely saying that scientists are citizens. When scientists use public funds, they are citizens with special responsibilities, so they should be especially aware of the values of the society that is funding them, and in planning their research, they should give consideration to those values. As Brown puts it: Don't tell the biomedical researcher which experiments to perform, but tell her



Irving Langmuir looked into blackened light bulbs and created modern surface chemistry

that "moving from remediation to prevention is a primary national and international goal." Don't tell an agricultural researcher what crop varieties to test, but rather tell him that the goal is to "feed a burgeoning global population without stripping the land of topsoil and nutrients, or massive pesticide use."

An example: DNA discovery

Who discovered that DNA was the material that carries the hereditary message, and how did they do it? I suspect you're about to say, "James Watson and Francis Crick" and that they managed to squeeze in a bit of research at Cambridge University between tennis games and trips to the pub.

Actually what Watson and Crick discovered was the double helix structure of DNA. The identification of DNA as the hereditary material was made by Oswald Avery and his colleagues at the Rockefeller Institute in the 1940s.

The reasons I bring up Avery's work are because it is one of the greatest truths discovered in the 20th century and because it was not undertaken as an unfettered, curiosity driven search for truth. In fact, it was undertaken for a very utilitarian purpose, strategically guided by a national health care need of the time: the battle against pneumonia. Avery was aware that the pneumococcus bacterium came in two varieties, one with a rough coat and the other with a smooth coat. Only one of them causes the disease. If you could transform the virulent form to the benign, you could perhaps prevent or cure pneumonia. So Avery had both a utilitarian purpose and a strategy.

But in the course of carrying out that strategy, he discovered a "transforming principle" that transcended his original aim—namely, that it was the nucleic acid DNA that determined whether the bacterium grew a rough or smooth coat. From that purposeful research program grew the focus on DNA that has proved so correct and fruitful.

Obviously Avery did not begin his work thinking, How can I create a biotechnology industry that will generate jobs? But in the end, he did help create that industry, and it is generating jobs.

Other examples

You're probably familiar with other examples. Louis Pasteur looked into problems of the French beer and wine industries, and came up with fundamental discoveries in biology. Irving Langmuir looked into blackened light bulbs and created modern surface chemistry. Karl Jansky listened to radio static and created radioastronomy. The research leading to the discovery of the transistor effect was undertaken at Bell Labs because of the explicit recognition that vacuum-tube technology would fall short of meeting the telephonic needs of the future.

Time and again, work undertaken in the search for utility has led to new understanding, just as work undertaken in the search for understanding has led to utility. The point is not which comes first. It's in the interconnection and positive feedback that is the basis for the social compact between science and politics.

We need to tell politicians that we share their constituents' concerns—creating jobs for their children and grandchildren, improving health, fighting crime, enhancing education. The best way we can do this is the way Avery and Pasteur and Langmuir did it: by recognizing, as only we can do, what new things we must learn about nature or what pioneering concepts need to be invented to address these concerns. We need to be responsive when we *begin* our research.

The technical barriers—like Langmuir's blackened light bulb—that practitioners encounter in their daily work can be just as rich a source of frontier research as what we learn from journals and scientific meetings. Embracing political, social and economic goals, far from being a hindrance to the science enterprise, will enrich it.

I believe there is an approach that is not only responsive to political and social concerns, that is not only consistent with the best values of science itself, but that can even enrich the scientific enterprise and make it more rewarding to the deepest interests of scientists.

Is this what George Brown and Barbara Mikulski have in mind? Probably not exactly. Is this what the scientific community has in mind? Not exactly. Is it an approach that both can understand, and in which both can see new opportunities? It will take discussion and an evolution in the quality and sophistication of the dialogue, but I believe the answer is, Yes. It can be a founding concept for the new compact that many now seek.

Notes

1. G Wise, Osiris 1, 229 (1985)
2. Congressman Boehlert, a leader in the opposition to the SSC, is a good personal friend, and I'm sure he won't mind the literary license I've taken in this context. ■

REGAINING A VOICE - PHYSICISTS IN FEDERAL POLICY

Roland W. Schmitt
PresidentEmeritus - Rensselaer Polytechnic Institute
Troy, N.Y.

An Address to The American Physical Society on the Occassion of Receiving the Pake Prize at Seattle, Washington on March 22, 1993

I am pleased to receive the Pake Prize from the American Physical Society. I have admired George Pake as a scientist and as an executive for many decades and there is no prize I cherish more than one honoring him.

My own interests for the last couple of decades have centered on industrial research and on federal and state policy for science and technology. When I entered a career in physics in the 50s physicists were among the most prominent forces setting federal policies. Today, the physics community feels that it is not being heard as clearly and is not as influential as it used to be. This lecture has given me the opportunity to reflect on this perception and to see what we may do about it.

What I will say is simple: We will regain a voice and influence by more actively listening to and responding to the needs of our fellow citizens, by talking to them about physics in terms that are important to them, by sometimes eschewing the arguments that appeal to us but have little meaning to them. It is my belief that doing things important to other people also gives you greater leeway to do things important to yourself.

Ever since World War II thrust the world into the nuclear age and vastly amplified the voice of physicists in the policy councils of the nation, physics has had something unique to say in those councils. The cold war may be over, new problems may have come to the fore, but the need for that unique voice of physics remains.

The uniqueness of todays situation, may seem to need no elaboration.

In what other era could a distinguished scientist, on leaving a congressional hearing, note to a friend that "Congress is ready to spend money for science, as long as it receives assurances that scientific results are not the main object."

In what other era would we hear of the most distinguished of our national laboratories cutting staff by 40%. . . . the major corporate labs eliminating some 50% of their physics positions . . . , and the number of government funded fellowships in physics dropping by over 60%.

In what other era could we hear a president of the United States saying that "a great deal of basic research has been done. I think the time has come to zero in on the targets by trying to get our knowledge fully applied."

As you may have already guessed, <u>all</u> of those things <u>did</u> occur in <u>other</u> eras. The first statement, about spending money on science as long as it wasn't buying scientific results, was made by the astronomer Simon Newcomb in 1886, after appearing before the Allison Commission, the first in-depth congressional look at U.S. science policy.

The data about cuts in national and corporate labs were from 1933.

The president who urged scientists to get their knowledge fully applied was Lyndon Johnson, speaking in 1964.

My attempt to fool you was not entirely frivolous. It's an attempt to establish a baseline.

In a long range perspective, the pre-eminence of the physical sciences was not pre-ordained at the time of the big bang. In fact, in relation to government science policy, it is a twentieth century phenomenon. As the best historian of American Physics, Daniel Kevles, reminds us, "in the late 19th century, the scope of Federal science ... did not include physics as such."

The second example, with its reference to the depression, reminds us that that worst of times was also the best of times. It's true that some major institutions suffered major cutbacks in the 1930s. But those institutions rebounded to levels far beyond their original state. In part, this happened because some courageous leaders such as Mervin Kelly at Bell, and William Coolidge at GE, did not lose heart. In the thirties they planted the seeds that would later lead to the transistor at Bell end man-made diamonds at GE. But the best of times mainly happened at universities, such as Stanford, Caltech, Berkeley, Wisconsin, Michigan, Rochester, MIT and Princeton. American physics matured not merely by attracting refugees from Europe such as Fermi, Wigner, Bethe and Von Neumann. It also drew the first generation of world class American-raised physicists, such as Rabi, Lawrence and Feynman.

Finally, the 1964 quote by Lyndon Johnson reminds us that even in the golden age, pressures for relevance were not absent. The normal situation has always been what Kevles defined as an uneasy tension between science and democracy.

There really was a golden age. That is no myth. It began beneath that squash court at Stagg Field in Chicago half a century before last December, and petered out sometime between the day in 1969 when American feet trod the moon and the day in 1973 when Arab oil ministers turned off their pipelines to protest a Mideast War.

But that golden age began and was sustained by unrepeatable conditions--based not so much on faith as fear. Scientific excellence was never accepted as a good in itself, but rather as a way of beating someone. First beating the Germans, then the Russians.

The peak of the golden age occurred in 1961, when Time Magazine's collective Man of the Year was 15 scientists, and John Kennedy's most memorable White House dinner hosted science Nobel laureates and other culture heroes, and included the famous line "this is probably the greatest collection of genius ever to grace this room with the possible exception of when Thomas Jefferson dined alone."

But when the Kremlin collapsed, the rationale crumbled. Our new threat, the Japanese, were clearly not using pure science leadership as a weapon.

So the golden age was fueled by unprecedented and unlikely-to-be-repeated circumstances.

Let's turn to the physicist's voice. It's logical to expect that the end of the golden age, and the removal of the Soviet threat, should diminish the voice of physicists in the national councils.

But, let's look at that assumption. I recently asked a friend who has taught history of science at Rensselaer to perform some quick and dirty quantitative experiments to find out if there was objective evidence that physics was losing its voice.

I set as my criterion the presence of physicists in the science policy positions that were likely to be listened to. First, we looked at the pre 1945 period in books about U.S. science policy, such as A. Hunter Dupree's classic Science in the Federal Government, and Dickson's The New Policy of Science.

We adopted the premise that if a book is about the making of national science policy, then the index of the book gives a pretty good indication of the names of the people who have had important voices in the making of national science policy. The share of physicists among those names should give a very rough measure of physics' voice.

By this measure, for the period up to 1940, about 10% of the names of the people involved in making science policy on a national level in the U.S. were physicists. Remember, this was an era in which such physicists and astronomers as Joseph Henry, Henry Rowland, Simon Newcomb, George Ellery Hale, and Robert Millikan were active.

For 1945-1966, the physicists' share jumped to about 25%. Recall that physicists are only about 6% of the people mentioned in American Men and Women of Science, less than 3% of US scientists and engineers, and very much less than 1% of the total population. So that 25% of voice is a remarkable figure.

For the post-65 era we went to the Prune Book, which lists the 60 toughest--and most important--science and technology positions in the Federal government. The book listed holders of jobs for the years 1969 through 1990. Reference to Who's Who and American Men and Women of Science made possible identification of the background of the job holders.

Here's the result. The physicists' voice indeed declined--but only from the 25% of key jobs held in the 1960s down to about 20% of the key jobs held in 1990.

What stands out from this quick and dirty study is that any loss of voice by physics has not been from a loss in the number of those in important federal positions who can speak for us.

So the troubles of today must come from what we say, not where we are or how loudly we speak. Are we saying things that are just not interesting to others? Are we speaking with a voice that seems to come from just another special interest group, espousing positions and goals that appeal to ourselves but to no one else?

Let me illustrate the point. Many physicists have campaigned to have individual investigator awards become the central focus of our appeal to the federal government - especially Congress - for increased funding of academic research. They have been opposed to the growth of center-oriented programs at NSF, for example. Their arguments have had some effect. During the congressional hearings on the fiscal 93 budget for NSF, the importance of individual investigator awards was emphasized more heavily than ever. The result, for the first time in my eleven years on the National Science Board, was a decrease in the NSF appropriation for research. I do not want to ascribe a too close cause and effect relationship between the argument and the result but I do think that other arguments would have been more persuasive and had a better effect.

In my view, physics and physicists cannot promote our cause by going the route of a special interest group: we have no chance of becoming the National Rifle Association of science! And it wouldn't be appealing to us to go this route. Yet, when we rely on arguments that appeal to ourselves but to few other people, we're behaving as if we had real power as a special interest group. It isn't the way to go.

What is the answer? I find it in a story with roots not in the golden age, but the depression era that preceded it.

That story is the discovery of radar. That story occurred many times and many places. but my favorite of the many discovery stories is the one told by the physicist Sir Robert Watson Watt. His team discovered radar in about the most unlikely way imaginable--by actively listening to a government bureaucrat!

A Government bureaucrat came to Sir Robert in 1936 with a very bad idea. He'd heard about an electromagnetic death ray that would knock planes out of the sky or at least cause the spark plugs of an engine to fail, or blind the pilot.

Rather than simply laughing, Watson Watt agreed to make the calculation. While making it, he thought--maybe we can't make a death ray, but we certainly can reflect enough energy to detect a plane at a long distance. The radar that won the Battle of Britain was born.

The story may be myth, but the point is sound. Physicists speak most loudly to society when they first listen to it. That was the lesson of the golden age, that will be the lesson of today.

Time and again, a scientist has listened to a real world problem, and found in it a way to contribute not only to society, but to science as well.

Louis Pasteur, facing the problem of spoiling wine, discovered and launched the field of bacteriology; Irving Langmuir, starting with a blackened light bulb, launched modern surface chemistry: Karl Janssky, listening to static, launched radio astronomy.

We, too, can find new activities and programs to link basic and academic researchers more closely to the problems being encountered by practitioners. The Carnegie Commission, in one of its fine studies of science and technology in the U.S. today has addressed the issue of "Linking Science and Technology to Societal Goals". Physics, among all the sciences, is well suited to making that linkage.

We've got an awful lot going for us.

Physics has a mode of thought and a pattern of concepts that work in many fields of importance. An outlying example is the pioneering work that physicists did, over two decades ago, in developing the random walk model of the price of stocks and, more recently, in exploring the applicability of chaos theory to stock market behavior. Physics concepts permeate other areas of science and engineering. The net flow of ideas between physics and these other fields is strongly outward from physics. Physics does have a legitimate claim to being the mother of the sciences.

There is a lot of talk today about whether physics will end when the next "wave of great discoveries" resolves the misfit between relativity and the standard model, discovers the nature of dark matter, and finds the ultimate, irreducible laws of physics. Whatever view that elementary particle physicists, cosmologists and their kindred may have of that great but elusive moment, physics will not end for the rest of us. Physics is replete with laws that, as Frank Wilczek describes in an elegant essay in Dicover Magazine, "emerge from regularities in the collective behavior of fundamental particles or molecules". He continues, 'Even if all the most basic, irreducible laws were known, we would still face the challenge of learning their consequences". I would add that we will not even recognize all of the consequences the emerging laws might have without moving beyond our self generated interests, without linking to other sciences and to the barriers encountered in the practical affairs of industry and government. We will be challenged the more, find more opportunity, become more creative, the wider we cast our net for places where the physics mind can work.

In fact, we might need some of the best minds in physics, as well as all of science, to recognize the fundamental significance of the barriers encountered in daily practice. What would have happened had Pasteur, Langmuir or Jansky been lessor lights? Would bacteriology, surface chemistry and radio astronomy have emerged from soured wines, blackened light bulbs and radio static? I think not. There is no less creativity and imagination needed in seeing the hints that nature gives us in our practices than those it gives us in our laboratories.

We entered the golden era when we found that that physics mind could work to create weapons, a need that we may not have welcomed or liked, but one that was real for the world around us then. Today, the most important needs of our globe are more benign, more satisfying to fullfill. It would be a shame if physics did not rise to these challenges as it did to the challenges of hot and cold wars.

There is another reason why we should become more engaged with the world outside physics. We are producing many students that are having trouble finding jobs; the problem does, in fact, seem to be more severe among physicists than in some other scientific and technical professions. I believe it is another symptom of the restrictive nature of the "standard model" of physics that's in the heads of most of us. The rest of society sees us as creative, to be sure, as intellectually powerful, to be sure, but as not interested in things that will help them.

If we change this, we will not only regain a voice, we will re-establish physics as a subject of importance to people other than physicists themselves. And we need to produce students who are interested in putting their talents to work in other fields as well as our own.

There's a story from the golden age of two 1920s vintage physicists at a late 1940s APS meeting, looking around at the flood of bright young people now in the field. One turned to the other and said, "I don't know any of these people." The other turned back, and said, "Yes--and what's worse, they don't know you!"

Well, I'd like to conclude with the words of two physicists who may mark among their assets that they may not know George Pake and they certainly don't know Roland Schmitt!

One of them is Tina Kaarsberg. Here's what she said in putting her name forward for the executive committee of the APS Forum--quote:

"I would like to expand the Forum's scope. I believe this expansion is also necessary as the importance of 'national security' in which physicists were preeminent, shrinks. Policy makers are asking all researchers, even those doing basic research, to justify their funding. They want science to help increase exports, to protect our environment and to cure cancer and AIDS and do all of this cost effectively. Where do physicists fit in? We in the Forum need to talk more to each other and to scientists in other disciplines to contribute to this discussion." Unquote.

Dr. Kaarsberg--right on!

The second is a spiritual successor to George Pake and myself, Nathan Myhrvoid. He was born about the time the golden age was peaking. He earned his Ph.D. for a thesis at Princeton on "Vistas on Curved Space Quantum Field Theory". He left physics to start an entrepreneurial venture in the field of software. Today he is director of R&D at Microsoft. He's most famous for his 100 page memos. But he expresses the essence more succinctly. As he puts it--"I want to spend my career on very hard, but not insoluble, problems."

In that spirit I leave you. Physics is facing very hard, but not insoluble problems. It's facing severe, but not unprecedented stresses. It's really returning to long term reality. Physicists have not lost their voice. They have not lost the opportunity to send out signals on some unique frequencies. . . signals that can be heard above the din of turbulent times. . . signals that will resonate and echo to the crucial issues of our time.

As we send signals out on these frequencies, we also need good receivers. We need the signal processing apparatus to understand how science and technology in general, and physics in particular, can better address today's social and economic issues while still stimulating the most innovative discoveries and creative new ideas.

Physics and physicists can do this and thereby reclaim a prominent spot in federal councils - it is worth our best efforts.

Questions for the Record from Senator Kennedy

Indirect Costs

1. **QUESTION: The National Science Board has taken the position, in a recent resolution, that a freeze in levels of indirect cost payments to universities will have a detrimental effect on the university research system. Could the Board explain the basis for its position?**

ANSWER: The long-term partnership between the Federal government and academia has been extremely successful in establishing and maintaining an academic research and education enterprise in this country second to none. The National Science Board believes that it is important that the Federal government not undermine the basic relationship which has benefited academic and Federal partners and the nation as a whole. Between 1991 and 1993 the universities and the Federal government successfully engaged in a detailed process of consultation to revise OMB Circular A-21 cost principles. The proposal for a year-long pause has been made outside of that process.

A year-long pause in indirect costs would leave institutions which exceed their prior year's performance in the competitive grant process with the choice of either declining to undertake Federally-funded research without indirect costs, or shifting the funding of those costs from other university sources. Given current constraints on other funding sources and the short time frame, it is likely that such costs would be covered by tuition and fees. If the choice, or only alternative, of an institution were to decline an award without indirect costs, it would mean that research deemed of high potential by the Federal government would not be performed. The proposed pause will affect the most successful research institutions in the coming year.

Expenses for facilities operation and maintenance are approximately half of the indirect costs provided through federal grants. Reduction in this source of support to facilities might be partially absorbed through deferred maintenance or lower availability of these resources.

The following resolution has been adopted by the National Science Board:

RESOLUTION APPROVED BY THE NATIONAL SCIENCE BOARD
AT ITS 320TH MEETING ON MARCH 18, 1994
CONCERNING A PROPOSED "PAUSE" ON
REIMBURSEMENT OF INDIRECT COSTS OF RESEARCH

Background

The partnership between the Federal government and the nation's colleges, universities and other non-profit performers of research has served the nation well for half a century by producing the talented people and new discoveries that opened up a range of economic opportunities and contributed to meeting a variety of national needs. That partnership is now threatened by a government proposal made without consultation with the research community, one which would have important negative effects on the nation's research enterprise. Recent negotiated changes in the rules for reimbursing indirect costs are already resulting in significant reductions, and there is no reasonable, non-arbitrary basis for further cuts at this time.

The proposed FY 1995 budget would cut Federal costs by approximately $130 million through the application of a "pause" in payment of indirect cost recoveries for grants to the nation's colleges, universities and other non-profit institutions significantly involved in research. The precise mechanisms for the application of this "savings" have yet to be determined, other than that institutions have been informed that they will receive no additional indirect cost reimbursements in the next fiscal year beyond the level that they are receiving in the current year.

Indirect cost payments for Federally funded research efforts are reimbursements for real expenditures that have actually been made by the participating institutions. The refusal of the Federal government to fully pay its previously-agreed share of these expenditures shifts that burden to other sources of institutional revenues, such as tuition, private gifts, and, in the case of public institutions, State appropriations Not only is such cost-shifting inappropriate, but, for some institutions, may not be possible for legal or organizational reasons

Payments to academic institutions for incurred indirect costs have already been reduced by changes in the revised OMB Circular A-21, released in spring 1993. Total recovery of legitimate and long-standing administrative costs has been capped at a rate of 26 per cent, even for those institutions that can document larger costs resulting from Federal programs. Furthermore, institutions have been complying with Federal policy that encourages multi-year cost rate agreements -- the results of which would now be put aside as a result of the proposed "pause."

Resolution

WHEREAS, the Report of the National Science Board Commission on the Future of the National Science Foundation declared in November, 1992 that "As a result of the government's reliance on universities for much of the nation's basic research, American graduate education in the sciences and engineering leads the world;" and,

WHEREAS, Federal payments for indirect costs are reimbursements for monies expended by an institution for recognized, legitimate purposes, including compliance with Federal standards and regulations; and,

WHEREAS, one of the long-standing guiding principles for the relationship between the Federal government and the nation's research institutions is that the government pay the full indirect costs of the research it supports; and,

WHEREAS, to expect universities to further subsidize the Federal share of costs legitimately incurred on Federal contracts and grants undercuts the Federal objective of investment in the nation's research enterprise and may shift costs to students, their families and State government taxpayers, and/or reduce the level of the nation's research activity;

Now therefore be it

RESOLVED, that the National Science Board register its strong concern over the implications of the recommendation for a "pause" in the FY 1995 reimbursements to institutions of costs incurred in the conduct of Federally-sponsored research, as inconsistent with the most effective use of Federal resources in pursuit of science and engineering excellence;

and be it further

RESOLVED, that the National Science Board recommends that the Office of Management and Budget work with the Assistant to the President for Science & Technology and representatives of the nation's colleges, universities and other non-profit institutions significantly involved in Federally-sponsored research to identify alternative means of meeting the requirements of fiscal constraints that will not jeopardize the fundamental principle of partnership between the Federal government and research institutions.

Supply of Scientists

2. QUESTION: During the 1980s, NSF projected a shortage of scientists in this decade. Congress funded programs to encourage students to pursue Ph.D.'s in the sciences. Today I hear reports of an oversupply of scientists in some disciplines. Is there really an oversupply of scientists? What steps, if any, should the National Science Foundation, the universities or industry take to address this situation?

ANSWER: Research, development, and associated technical and managerial positions in defense companies are being cut back sharply Positions in Federal energy and defense laboratories are quickly being reduced, and the very roles and missions of those institutions re-thought In addition, over the last three or four years, the decades-long expansion in academic tenure-track positions has sharply and unexpectedly reversed, due in part to cutbacks in appropriations by many State governments to their public colleges and universities and in part to economic constraints on privately-governed institutions Thus, in some fields, Ph.D. graduates have encountered difficulty in finding academic positions.

New policies must be developed to deal with these new realities. The nation needs to maintain a robust and creative research and higher education system to continue to create new industries, to provide workers with the skills they need to perform in technical fields, and to find better ways to deal with other societal issues such as improving public health, limiting and repairing environmental damage, and raising the level of public education. Simply cutting back the overall number of people going on to higher education in the sciences and engineering would undercut those objectives, and as well the related and highly important objective of further diversifying the nation's base of talented researchers and teachers.

Consistent with its February 1994 statement "Toward the Next Century: the State of U.S. Science and Engineering" (attached), the National Science Board has embarked on issues related to policy on human resources development in science, mathematics, engineering and technology. The Board expects to be heavily involved in studying these issues over the short term, and then helping to lead the national discussions on ways to cope with the fundamental changes that have taken place. Accomplishing effective and lasting policy changes in this area must involve well-thought-out actions by Federal and State governments, colleges and universities of all types, and private-sector employers.

A VIEW FROM THE NATIONAL SCIENCE BOARD

TOWARD THE NEXT CENTURY: THE STATE OF U.S. SCIENCE AND ENGINEERING

I. Introduction

The National Science Board (NSB) is charged with focusing national attention on major issues of science and engineering research and education. An important aspect of this responsibility is the publication of *Science & Engineering Indicators*, a biennial report of data and trends on American research and education in the sciences, mathematics, and engineering. This report, submitted to Congress through the President, provides a quantitative overview of the health and achievements of the science and technology enterprise. To accompany *Science & Engineering Indicators - 1993*, the Board presents this statement highlighting issues that must be addressed by the Nation to maintain continued U.S. leadership in science and technology and to assure the productivity of our research and education systems.

II. The Changing Context for American Science and Engineering

"Investing in science and technology is investing in America's future." [1]

William J. Clinton
November 23, 1993

The 11th issue of *Science & Engineering Indicators* appears at a crucial time. As the 20th century draws to a close, the world is reaping the benefits of a half-century of broad based Federal investment in science and technology. The knowledge produced by scientists, mathematicians, and engineers has dramatically increased agricultural production; it has created new industries such as semiconductor manufacturing and biotechnology; it has connected the world with information networks; and it has created the means for a dramatically healthier and longer lifespan.

Science and technology will be even more important in the next century. With the end of the Cold War and the rise of a global economy, national and international goals for science and technology are being shaped by new forces of economic interdependence and competition. The knowledge produced by scientists, mathematicians, and engineers must be utilized to foster sustainable development in all nations and to contribute to the solution of global problems.

Within the new international context, the health of the U.S. economy and the competitiveness of our industries rely increasingly on the exploitation of scientific and technological advances and on the availability of an adaptable, educated, and technically prepared workforce. The growing internationalization of science and significant improvements in human resources and research capabilities of other nations require that the United States maintain and enhance its own capabilities to take advantage of discoveries around the globe.

The next few years will be critical for establishing the policy directions that will guide us in the new era. In the transition to a new political and economic framework, it is vital that the United States maintain the momentum generated by decades of sustained growth and commitment to excellence in science and engineering. The ability to do good science, and to do good with it, are not guaranteed. Both will require investment in all components of the system—industrial research and development (R&D), national laboratories, and academic institutions—as well as in areas of strategic importance requiring special attention.

III. Trends

Investment in Science and Engineering

The United States still leads the world in total national and industrial R&D investment[2] and continues to set the standard for excellence in research and higher education. At the same time, there are concerns about U.S. performance in the global context.[3]

Other countries are closing the gap with—or are even leading—the United States by some measures.[4] Newly industrialized countries have sharply increased their investment in science and engineering. As one result, in 1991 the combined natural science and engineering baccalaureates of six Asian nations exceeded those of North America and Europe taken together.[5]

Total national R&D expenditures, adjusted for inflation, rose rapidly from the mid-seventies through the first half of the eighties. However, since 1985 they have been virtually flat.[6] Furthermore, as noted by the recent NSB report, *The Competitive Strength of U.S. Industrial Science and Technology*, ". . . the real rate of growth in U.S. industrial R&D spending has declined since the late 1970s and early 1980s."[7]

The current Federal R&D budget reflects continuing adjustment to post Cold War priorities and renewed focus on civilian needs. In particular, over the last decade defense spending has declined from 69 to 59 percent of the Federal R&D budget.[8] Nevertheless, despite the increasing importance of civilian research to innovation and economic growth, we continue to lag behind some other industrialized nations in the percentage of the gross domestic product devoted to nondefense R&D.[9]

Colleges and universities continue to increase their share of national R&D.[10] But Federal funding as a proportion of the total support for university research has declined since 1980 while the contributions from industry, state and local government, and universities have increased. Also, in spite of greatly increased university investment in research facilities and instrumentation, a substantial proportion of academic research space is in critical need of renovation and repair, and research instrumentation needs have grown.[11]

Human Resources and the Workforce

The public attitude regarding both the value of continued investment in science and technology and the importance of education to achieving personal and national goals remains strongly positive.[12] At the same time, the American public's level of scientific literacy and general technical preparedness are not adequate to meet the needs of the changing economy.[13] A productive, adaptable, and skilled technical workforce for all sectors of the economy depends on the quality of the Nation's education system at all levels. Consequently, the state of education in science and mathematics at the precollege level remains a major national concern. In international comparisons, the United States continues to lag behind the highest achieving nations, even when comparing our best school districts with their national performance.[14]

The U.S. system of higher education is facing new pressures and financial constraints. Enrollments in institutions of higher education continue to rise, and the student body has become increasingly diverse with respect to age, ethnicity, and walk of life. At the same time, the absolute number of undergraduate degrees awarded in engineering, mathematics, and computer sciences continued to decline in 1991. However, the increase in full time undergraduate engineering enrollments from 1990 through 1992, after a 9 year decline, portends a rise in degrees in the coming years. While women and African American, Hispanic American, and Native American minorities have increased their representation in science and engineering disciplines, their participation rates remain unacceptably low.[15]

Two-year institutions have absorbed most of the increase in college enrollments in recent years. But associate degrees in engineering technology, mathematics, computer sciences, and engineering have fallen since the mid-1980s.[16] Declining interest in these degrees in 2-year colleges has special significance for efforts to increase participation by groups traditionally underrepresented in technical disciplines—groups that form a disproportionate share of the enrollment of 2-year institutions.

Job opportunities and salaries for recipients of science, mathematics, and engineering degrees remain better than for other disciplines.[17] But there has been a decline in overall science and engineering employment rates. In some fields, high proportions of new Ph.D recipients are taking post-doctoral positions, and part-time employment is becoming more common at universities and colleges. Some professional associations also report extended time for job searching for Ph.D. graduates.[18] A much more pessimistic outlook pervades defense-related industries. In engineering occupations, downsizing among some industries and reduction in defense spending have contributed to a doubling of the unemployment rate from 1987 to 1992.[19]

Partnerships and Institutional Concerns

Partnerships and cooperative arrangements in science, mathematics, and engineering research and education are becoming more important and prevalent both domestically and internationally. The excitement and importance of multidisciplinary research, the cost savings achieved through shared facilities and resources, the more rapid diffusion of knowledge, and the explosion of information networks—all these factors have provided powerful incentives for the increase in collaborative approaches.

In the United States, cooperation in R&D activities within and among sectors increased rapidly over the last two decades. Activities such as university-industry research centers, multi-firm R&D alliances, and coauthorship of scientific articles have increased.[20] States have become important players in promoting cooperation at the local level.[21]

For the Federal Government, the continuing need to encourage innovation and to ensure the most effective use of scarce financial resources has resulted in a stronger focus on cooperative activities. The reorganization and downsizing of defense-related activities underscore the urgency for national laboratories to cooperate with the private sector in defining new missions with benefits to civilian needs.[22]

IV. Issues and Actions

> *"Science, by itself, provides no panacea for individual social, and economic ills; it is effective in assuring the national welfare . . . as a member of a team . . . [But] without scientific progress, no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world."*[23]
>
> Vannevar Bush, 1945

Investment in Science and Technology

A robust knowledge base appropriate for economic growth, long term job creation, protection of the environment, and social well-being requires a conscious commitment to strong and consistent long-term support for research and education as a part of a balanced portfolio of activities and investments. A coherent national science and technology policy, a stronger industrial research effort, and a refocused mission for Federal laboratories are essential components of this commitment. Equally critical, as stated in the May 13, 1993, NSB white paper, *In Support of Basic Research*,[24] is a strong foundation of basic research.

The process of research in fundamental sciences and engineering expands the knowledge base and directly contributes to strategic national goals through pioneering discoveries and the continued development of a cadre of educated people who are the source of new solutions and new opportunities. Apart from its contributions to specific areas of national importance, the overriding strategic value of basic research resides in going beyond research areas and questions whose utility is understood to those whose applications have yet to be discovered. As noted by industry leaders in a recent report, the primary value of the university is in basic research and education. These activities require and deserve stable Federal support.[25]

Recommendations:

- *An increased fraction of savings resulting from cuts in defense R&D spending should be redirected to dual-use technologies and support of civilian research priorities in strategically important areas.*

- *A national initiative should be established for the renovation and modernization of university research facilities and major capital equipment.*

A Technically Prepared Workforce, A Scientifically Literate Public

A technically competent and scientifically literate workforce drawing on a diverse and talented population is essential to this Nation's future. Changing labor market conditions for scientists and engineers—and the broad-based requirement for a more technically trained, qualified, adaptable workforce and citizenry—require continued national leadership to ensure quality education at all levels. Increasingly important in this context is the coordination of the educational process with the present and future needs of the marketplace.

Recommendations:

- *Mathematics, science, and engineering curricula at all levels of education should be evaluated to ensure that all students obtain the background needed for the workforce of the future. Appropriate education should be responsive to workforce needs and opportunities in industry and government as well as universities.*

- *Federal agencies must increase their cooperation with state governments, educational institutions, and other groups in systemic educational reforms, such as those promoted by the National Science Foundation, to improve the quality of precollege education in the sciences, mathematics, and engineering.*

- *Building on successful models, Federal and state governments must redouble their efforts to increase the participation of women and underrepresented minorities. At the post-secondary level, special attention should be given to 2-year institutions, which have absorbed the great bulk of growth in enrollments and serve a highly diverse population.*

New Partnerships and Institutional Issues

The coming century will impose greater demands and responsibilities on all who have a stake in the discovery and use of knowledge. A more rapid pace of discovery, the increasing importance of multidisciplinary research, and the confluence of research interests and opportunities across institutional lines call for industry, academia, and government to supplement traditional modes of research support with creative approaches and relationships, both domestically and internationally.

Innovative institutional arrangements appropriate to the needs of complex multidisciplinary research teams have been the focus of many new government programs. These new approaches, complementing the work of individual investigators, must continue to be tested and successful models expanded. New university partnerships with industry respond to pressures for greater relevance to societal needs in research and education, and for more effective diffusion of knowledge and ideas from academic research to industrial applications. They also offer special opportunities to explore new research directions.

At the same time, the growing number of collaborative arrangements often results in more complex issues concerning conflicts of interests and individual property rights. Regional economic development initiatives, incorporating collaborative research arrangements between industry and academia, will call on states to assume a stronger, catalytic role.

Recommendations:

- *Federal agencies that provide substantial support for science and technology must pursue international cooperation more systematically in science, mathematics, and engineering research to expand the global knowledge base, increase diffusion of knowledge generated abroad to U.S. scientists and engineers, and share the opportunities of global research initiatives and expenses of operating costly research facilities and capital equipment.*

- *Clear guidelines are needed with respect to conflicts of interests and intellectual property issues as they apply to academic research.*

- *Federal and state governments must develop more coherent and supportive relationships with academic institutions to encourage a greater use of knowledge generated by academic research.*

A New Context for Science and Technology Policy

The new global environment and constraints on the Federal budget demand a fresh and vigorous national vision for public support of science and technology and better organizational and policy coordination within both the Executive Branch and Congress. Examples of important new approaches to rationalize Federal missions and processes in science and technology include the new National Science and Technology Council, chaired by the President, and its Fundamental Science Research Committee.

There is also a universally recognized need for greater accountability in the planning and implementation of all government missions, including support for research and education. Important Administration efforts to increase the efficient use of resources call on agencies to emphasize: self-assessment; improved performance of their missions; close attention to priority setting and planning; and support for flexible, cooperative arrangements that take advantage of good ideas wherever they are found. New cross-agency initiatives, such as the Technology Reinvestment Project, that focus on the development of technologies serving both civilian and defense-related needs suggest productive models for leveraging limited research dollars.[26]

Recommendations:

- *All agencies should systematically assess their contributions to the Nation's R&D capacity, both by evaluating their own programs and increasing coordination with other agencies in areas of mutual interest.*

- *The science and engineering communities need to communicate to Federal sponsors and the public the linkage of their activities with national goals.*

- *Federal advisory and deliberative structures for science and technology should more systematically seek the input of private industry and other stakeholders.*

V. Conclusion

American science and technology are challenged by extraordinary opportunities to expand the knowledge-based horizons of humankind. Shaping a new national strategy for science and technology and the means to implement it and evaluate its success is the major task confronting Federal science and technology policy today.

---

1. William Jefferson Clinton, "Statement of the President" (Washington, D.C.: White House Office of Media Affairs, November 23, 1993).
2. National Science Board, *Science & Engineering Indicators - 1993*, NSB 93-1 (Washington, D.C.: Government Printing Office, 1993) p. xvii.
3. Ibid., pp. xvi, xviii.
4. Ibid., p. xvi.
5. Ibid., p. xvii.
6. Ibid., p. 91.
7. National Science Board, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues*, NSB 92-138 (Washington, D.C., National Science Foundation, 1992), pp. ii.
8. *Science & Engineering Indicators - 1993*, p. xxi.
9. *The Competitive Strength of U.S. Industrial Science and Technology*, pp. i-ii.
10. *Science & Engineering Indicators - 1993*, pp. xix, xxi.
11. Ibid., pp. 111-13.
12. Ibid., p. xxx.
13. Ibid., p. 3.
14. Ibid., pp. 16-17.
15. Ibid., pp. 31, 42-43.
16. Ibid., p. 18.
17. Ibid., p. 60.
18. For data on part-time positions, see: Science Resources Studies Division, National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States: 1991* (Washington, DC: NSF, forthcoming.) For other Ph.D. employment data, see *Science & Engineering Indicators - 1993*, pp. 76-78.
19. *Science & Engineering Indicators - 1993*, p. 60.
20. Ibid., p. xxii.
21. Ibid., p. 96.
22. Ibid., pp. 119-20.
23. Vannevar Bush, *Science — The Endless Frontier* (Washington, D.C.: National Science Foundation, reprinted May 1980) p. 11.
24. National Science Board, *In Support of Basic Research*, NSB-93-127 (Washington, D.C.: National Science Board, May 1993).
25. The Government-University-Industry Research Roundtable and Industrial Research Institute, *Industrial Perspectives on Innovation and Interactions with Universities: Summary of Interviews with Senior Industrial Officials* (Washington, D.C.: National Academy Press, February 1991), p. 20.
26. *Science and Engineering Indicators - 1993*, pp. 108-16.

NSF Organization

3. QUESTION: The organization of the National Science Foundation should optimize the Foundation's ability to fund projects in research and education that will ensure excellence in basic science while also supporting progress toward achieving our national goals. In the past, NSF has succeeded in this endeavor. Changing national priories, however, suggest that the NSF would benefit from a reexamination of its organization.

How does NSF's current organization ensure that the Foundation is responding effectively to the nation's needs as codified in the national goals? What are the strengths of the existing organization? Are there areas that could be more effective, and if so, what are they and why? You mentioned at the hearing that NSF has undertaken a process of self-examination to improve the way the organization will operate in the future. What is that process? What is the projected timetable for the self-study? Are there any preliminary conclusions which you would like to share with the Committee?

ANSWER: NSF's current organization maintains the Foundation's ability to encourage evaluate and support excellent proposals, whether in traditional disciplinary fields or in newer interdisciplinary areas of strategic interest. NSF is already responding to the nation's needs as codified in the national goals through means such as cross-directorate working groups, coordination between program managers, and contacts with the research community This approach is intended to break down walls between disciplines and encourage the research community to think more broadly about research applicable to national priorities. In addition, as part of the strategic planning process currently underway, we are working to examine the management structure for research in strategic areas, with particular emphasis on how a "matrix management" plan might best be implemented.

Although a single "best" organizational structure is elusive, I believe there are basic principles that should guide NSF. The first is that the organization be sufficiently flexible to recognize and take advantage of emerging fields of research and at the same time phase out research in areas that are less productive. The ability to support research that takes us in new and unexpected directions requires both organizational flexibility and an organizational culture that values the innovative.

A second principle is the ability to capture, indeed to encourage, research proposals that may reflect revolutionary approaches to problems. The difficulty in meeting this goal is only partly one of organizational structure, because any organizational structure can become entrenched and non-responsive. To adhere to this principle requires that the organization not be locked into a rigid disciplinary approach to addressing problems.

A third principle for NSF is the need to emphasize the integration of education and research activities. This is a critical factor in attaining NSF goals.

I believe these principles are best expressed through a matrix management design that assures NSF support for essential research that might not fit conveniently within one or another strategic area. I am developing a streamlined implementation of this concept which I plan to put in place early in FY 1995.

Substantial progress has been made in the strategic planning process currently underway. A Committee for Strategic Program Planning and a Strategic Planning Working Group have been convened. The planning process has several important objectives:

- Produce a vision statement that captures the core values of NSF;
- Establish goals in support of the NSF mission;
- Develop criteria to guide priorities; and
- Focus on accountability and public understanding of NSF.

The planning process will allow us to provide you with the framework of our revised strategic thinking by June 30, 1994. Strategic planning documents are currently being drafted and circulated for review and comment by NSF staff, and will be discussed with the National Science Board at its June planning meeting. This process should result in a shared vision of what we and the Board see as the direction of NSF in the near future. The final strategic plan will communicate this shared vision and will provide a basis for the setting of objectives, milestones, and performance indicators for each of the Foundation's major sub-units.

Systemic Initiatives

4. QUESTION: The State Systemic Initiatives to reform science and math education are a relatively new venture for the National Science Foundation which, before 1991, had funded smaller projects in the education field. In many ways, the State Systemic Initiatives represent the equivalent of "big science" projects in education.

What are the strengths and weaknesses of the systemic initiatives? In funding education, what balance should NSF strike between the systemic projects and projects initiated by individual investigators or organizations and how should that balance be determined?

ANSWER: The underlying premise of NSF's Statewide Systemic Initiatives (SSI) and other systemic efforts is that the attainment of world class standards in mathematics and science education will require the replacement of isolated and piecemeal reform efforts with more ambitious, coordinated, and coherent approaches involving many aspects of the system. The purpose of these programs is to build the capacity and infrastructure for science and mathematics education reform in states, cities, districts, and regions so that all students receive high quality science and mathematics.

The strengths of this approach are:

1. The development in each state of clear goals for what students should know and be able to do.

2. The use of policy instruments such as curriculum frameworks and student assessments for communicating ambitious learning outcomes throughout the education system.

3. The employment of a diverse set of strategies to achieve reform, including: model or demonstration schools, training lead teachers or school teams, development of new curricula, restructuring of preservice education, and mobilization of public opinion. These have resulted in building the capacity of school-level educators to implement reform.

4. The leveraging of SSI funds to obtain more than a 100 percent "match" of other funds to support SSI activities.

5. The integration of the SSI's into a larger series of existing state reforms.

6. The inclusion a variety of agencies, such as state government, institutions of higher education, businesses, and professional organizations in governance and collaboration.

7. The involvement of approximately one-quarter of the local districts in SSI activities.

The weaknesses of a systemic approach include those of any uncharted approach--there are no "road maps" to follow. In addition, these are large projects compared to most in education and require skillful leadership, strategic planning, fortitude, and flexibility to be successful. They must balance leadership from the top with involvement at the grass roots. They must demonstrate some early success without losing their long-term focus. They must not attempt to do everything at once and yet not leave out anything critical. They must include all stakeholders without having chaos.

The systemic initiatives are the heart of the operation of the Education and Human Resources Directorate (EHR). Currently, they account for some 20 percent of the EHR budget. The EHR strategy is to continue to fund modest increments in systemic programs, as the Urban Systemic Initiatives and Rural Systemic Initiatives come on-line and as the Collaboratives for Excellence in Teacher Preparation complete their funding cycle In addition, however, a variety of other programs, such as the Teacher Enhancement program and several programs within the Human Resource Development Division are becoming increasingly systemic. The remainder of the EHR portfolio will include many projects initiated by individual investigators or organizations. Increasingly, however, these projects, too, will focus on providing support for systemic reform, such as new curriculum or professional development materials and new assessment methods In addition, EHR will continue to fund opportunities for individual scholars and means for new and innovative ideas to be developed and tested.

The ultimate balance between these will depend in general on the results of evaluation and monitoring of the systemic initiatives and on an analysis of their needs and contributions. It is too early to specify this balance in exact percentages. It would appear, however, that approximately one-third to one-half of the EHR resources might ultimately go to systemic programs with one-fourth to one-third going to projects designed specifically to support them. Approximately one-sixth to one-third of EHR funds would then go to projects initiated by individual investigators or organizations.

Merit Review

5. QUESTION: One of the criticisms of NSF that we sometimes hear from constituents is that the peer reviews used by the research programs are drawn from an "old boy" network of academic researchers from a limited number of institutions. Is that criticism justified? What steps does NSF take to ensure that members of its panels come from diverse institutions and are themselves diverse with respect to gender and ethnic background?

ANSWER: NSF recognizes the importance of maintaining a process that is both deep in utilizing the expert opinions of leading researchers, and broad in the regional, ethnic and organizational backgrounds from which these researchers come. NSF has long-standing policies, programs and outreach efforts that are expressly designed to encourage women, minorities and persons from other than elite universities to participate fully in NSF programs The Foundation recognizes the need to broaden participation in our programs -- including the review process -- and encourages program officers to look for and include new individuals as part of the review community.

Because of legal considerations regarding privacy, NSF does not ask about the gender or ethnicity of reviewers nor is such information maintained in the database. Although NSF does not have any rules or requirements that mandate a program officer to use a certain number of reviewers with regard to ethnicity and /or gender, there are policies that peer reviewers should reflect a balance among several characteristics -- including geography, type of institution and organization, and underrepresented groups. These policies are incorporated in the Foundation's Proposal and Award Manual. Program officers choose peer reviewers with these policies in mind.

6. QUESTION: On a related issue, the National Academy of Sciences recently issued a report, Major Award Decisionmaking at the National Science Foundation, which contained concrete proposals for improving the review process used to make awards larger than $1.5 million in one year or $5 million over five years. Among the Academy's recommendations was the implementation of a uniform review of all proposals with a first review by a panel of technical experts followed by a second review panel involving representatives of other concerned groups to look at proposals of great technical merit. A second set of recommendations involved providing more careful documentation of all steps in the decision process. What is your view of these recommendations? What steps, if any, are you taking to implement some or all of these recommendations?

ANSWER: The NAS Panel's recommendations are under consideration by the Foundation to determine what changes may be appropriate. The Foundation's statement at the time of the report's release is provided below. As the Panel itself recognized, the majority of its recommendations are consistent with current NSF practice or would require minor changes; addressing the two mentioned in your question requires the most thought.

One of the Panel's recommendations, namely that the National Science Board should cut down on the number of major award items it routinely reviews, is consistent with the following resolution approved by the Board at its May 1994 meeting raising the dollar thresholds for Board review. This decision was the result of extensive examination over the last year by the Board itself of its roles and workload, and is intended to allow more time for policy development, long-term planning, and oversight.

ATTACHMENT A TO NSB-94-95

DELEGATION OF AUTHORITY

(1) The Director of the National Science Foundation (Director) shall make no award involving more than fifteen million dollars in total, or more than three million dollars in any one year, without the prior approval of the National Science Board (Board), except for any continuing project, facility, or logistics-support arrangement for which the Board has waived review.

(2) Except as provided in paragraph (1) or by specific resolution of the Board, the Board hereby delegates to the Director authority to make any award within the authority of the Foundation, consistent with the authority of the Board to approve the Foundation's programs.

(3) When the Board approves the award of a specific amount of funds, the Director may subsequently amend the award to commit additional sums, not to exceed twenty percent of the amount specified or ten million dollars, whichever is less, or to change the expiration date of the award.

(4) This resolution supersedes and replaces the resolution of the Board (NSB-91-69) on this subject adopted in 1991.

The Panel's statements about a two-phase review process specifically refer to the second phase as involving additional peer experts "qualified to evaluate proposals on both the additional criteria and the technical criteria identified for that project." The Panel did not suggest involvement of "representatives of other concerned groups".

Statement
on the release by the National Academy Press of the report
"Major Award Decisionmaking at the National Science Foundation"

The National Science Foundation and the National Science Board have received the report of the Panel on Decisionmaking for Major Awards of the National Research Council. The report focuses on the process of decisionmaking by the National Science Board about proposed research projects, programs and facilities that have significant amounts of funding and/or significant policy or management implications Thus the report's recommendations are particularly relevant to the role and operations of the Board

The Foundation periodically evaluates its proposal review system and adapts it, as appropriate, to new needs and circumstances This report, requested by Congress, was produced by a distinguished independent panel operating under the guidance of the National Research Council's Committee on Science, Engineering and Public Policy, which includes experienced members of the academies of Science and Engineering and the Institute of Medicine.

We welcome constructive recommendations in the spirit of continuous improvement of what is widely recognized to be an excellent system for support of research throughout the nation. We will carefully review the report and its recommendations and respond in detail when we complete our review

Academic Research Infrastructure

7. QUESTION: The most recent set of proposals for the academic research instrumentation program was due March 15, 1994 and proposals for the academic research facilities modernization program were due April 5, 1994. How many proposals have you received under each program? What is the total amount of funding requested under each program? What proportion of that total do you consider to be of sufficient technical merit to deserve funding?

ANSWER: A healthy and productive U.S. science and engineering enterprise requires access by the academic research community to state-of-the-art research facilities and instrumentation. NSF's academic research infrastructure activity consists of two components--facilities modernization and major research instrumentation. An integrated approach is needed to improve the condition of both research equipment and facilities at universities and colleges.

In response to the solicitation for research instrumentation, 420 proposals have been received requesting approximately $174 million. In response to the solicitation for research facilities, 281 proposals have been received requesting approximately $226 million.

NSF relies on merit based peer review for funding decisions. In the Fiscal Year 1993 academic research facilities modernization competition, the merit review panels recommended that NSF support approximately 46% of the proposals that competed. The panels that reviewed the academic research instrumentation proposals during the Fiscal Year 1992 competition recommended approximately 52% of the proposals for support by the NSF.

University Radio Astronomy Facilities

8. QUESTION: The Committee has received from the Foundation a copy of a report from an ad hoc committee known as the Taylor Committee. That committee was asked to review and advise the Foundation about the future for a number of university radio facilities. Would you review the findings of this report with the Committee and give us some sense as to how NSF will respond to the recommendations. Will NSF be terminating its support for any of these centers?

ANSWER:

Background. The National Science Foundation's Division of Astronomical Sciences (AST) presently supports five university-based radio observatories. These are (1) the Haystack Observatory of the Northeast Radio Observatory Corporation, (2) the Owens Valley Millimeter Array (OVRO), (3) the Berkeley-Illinois-Maryland Array (BIMA), (4) the Caltech Submillimeter Observatory (CSO), and (5) the Five College Radio Astronomy Observatory (FCRAO).

The five facilities share special strengths and common administrative and scientific characteristics. In particular:

- They play a unique role as educational resources, training a substantial fraction of astronomy's new Ph.D.s and the vast majority of new instrumentalists in the field.

- They act as foci for large, innovative research groups.

While all five university radio observatories operate scientifically and technically sound programs, within the past few years it has become evident that in order to facilitate growth and innovation within this sector of the AST program, a prioritization of facilities culminating in the measured withdrawal of support for one observatory, will be necessary.

Process

In the past 25 years, AST has withdrawn support from 13 university-based radio telescopes so that funds could be employed in support of newer or stronger programs elsewhere; the last such termination occurred in FY 1989. Nevertheless, it was decided that it would be desirable to involve the astronomical community as far as possible in the process of ranking currently-supported university radio facilities, with a view toward the probable withdrawal of support for the weakest program.

A committee of three distinguished astronomers, headed by Dr. Joseph Taylor of Princeton University, was selected by the Director of the Division of Astronomical Sciences. Dr. Taylor received the 1993 Nobel Prize in Physics for his research on pulsars. The committee was charged with producing a ranked ordering of the five university facilities according to the following criteria:

- Recent and probable future scientific productivity, as judged by both publication record and scientific accomplishment.
- The role each facility has played and can be expected to play in educating US radio astronomers, both instrumentalists and observers.
- The availability of observing time at each facility to the US astronomical community.
- Uniqueness and the role each facility plays as a component in the US radio astronomy program.
- The potential of each observatory for future instrumental and scientific development.

In order to fulfill its charge, the committee made intensive, one-day site visits to each observatory The committee was accompanied on these visits by the NSF Division Director for Astronomical Sciences and by the Unit Coordinator for Radio Astronomy Facilities, in order to keep NSF program management fully informed of the status and progress of the review. Each observatory also provided in advance of the committee's visit a basic information package describing the basic characteristics of the facility.

Findings and Future Actions

The Taylor committee's ranking of the five university facilities was:

(1) Owens Valley Millimeter Array
(2) Caltech Submillimeter Observatory
(3) Berkeley-Illinois-Maryland Array (tie)
(3) Five College Radio Astronomy Observatory (tie)
(5) Haystack Observatory

The committee noted that there was a substantial gap between the ranking of OVRO and the next three facilities; the committee also noted that there was a similar gap between the middle three observatories and Haystack.

At present, AST supports two programs at Haystack Observatory: single-dish radio astronomy operations of the 37m antenna, and research in very long baseline interferometry (VLBI).

Partly on the basis of the Taylor committee's ranking, AST will be making an orderly and measured reduction in its support of single-dish observations at the Haystack Observatory in Westford Massachusetts. These reductions will terminate with the cessation of all AST funding for this program at the end of FY 1997.

AST is working with the management of the Haystack Observatory to preserve a core program in VLBI beyond FY 1997; this is an area in which Haystack personnel have long been world leaders.

At the same time, AST is also striving to help Haystack define for itself an innovative role as an educational facility, an area in which the observatory has long been prominent.

LIGO

9 QUESTION: NSF has recently named a new principal investigator and project director for the Laser Interferometer Gravitational Wave Observatory in order to address certain management problems. To what extent will these changes affect staffing requirements, the project's schedule, its final cost and its budget over the next 3 years?

ANSWER: The organizational structure of LIGO is being modified to be more responsive to the needs of the project as it progresses from the stage of intensive research and development to construction. The staff is expected to increase by about 15 persons. The project schedule completion date is expected to remain unchanged.

NSF is now in the process of reviewing the cost of the project, with the assistance of an outside team of experts. Preliminary activities took place in early April. The current plan calls for the cost review to be completed by October 1, 1994, coinciding with the finalization of the details of the reorganization. The report will enable us to verify or correct our estimates. We will inform the Committee as additional information becomes available.

Support for Graduate Education

10. QUESTION: As you know, this Committee has been a strong supporter of a graduate traineeship program. We authorized such a program for NSF in P.L. 101-589, the Excellence in Mathematics, Science, and Engineering Education Act of 1990. The FY 95 budget request does not provide for any new awards, although it supports the 360 existing positions in traineeship programs. Why was this decision made? Was it reviewed with the National Science Board and what was their reaction?

ANSWER: The FY 1995 Budget Request for the Education and Human Resources (EHR) account reflects the priorities of precollege systemic reform, technological education and undergraduate education. In addition, a priority within the Foundation's Graduate Education and Research Development Activity was to increase the stipend and the cost-of-education allowance in the Graduate Fellowship program. This increase is essential because NSF's fellowship support has fallen below that of fellowship programs in other federal agencies.

When the National Science Board (NSB) approved the Foundation's plans for the FY 1995 Budget Request at its August 1993 meeting, a request for an additional class of traineeships was included. There was no formal discussion of the traineeship program; however, the NSB has expressed its support for traineeship programs in the past.

The NSB has begun examination of the traineeship issue in the context of evaluating the adequacy of education and training in the preparation of a workforce appropriate to meeting the diverse needs of the marketplace. The NSB Education and Human Resources Committee, with the assistance of the Foundation's EHR Directorate, has begun to explore different ways to provide financial aid for graduate education.

Biennial Report on Women and Minorities in Science and Engineering

11 QUESTION: As a result of the Equal Opportunities in Science and Engineering Act of 1981, the Foundation publishes a biennial report on women and minorities in science and engineering. When will the next edition of this report be available? Can you provide us with a preview of the trends and major developments which this report will likely show?

ANSWER: The 1994 edition of the report Women, Minorities, and Persons with Disabilities in Science and Engineering is scheduled for delivery to Congress in summer 1994.

Preview of Selected Findings

- The gender gap in mathematics achievement does not appear until age 17, and is seen in a smaller percentage of girls taking the highest levels of mathematics.

  Similar differences appear early across racial/ethnic groups. The reasons for these gaps appear to differ for gender and for race/ethnicity.

- Females tend to score lower on standardized tests (such as SATs for college-bound high school seniors) than males, although they earn higher grades than males at both high school and college levels.

- Underrepresented groups have made some progress in attaining credentials through the educational system. For example, women have increased their participation in undergraduate education, although their progress in science and engineering (S&E) fields has been slower than in non-science fields. Between

1981 and 1991, women increased their share of bachelor's degrees overall from 49.9 percent to 54.1 percent, reflecting their larger shares in enrollment. They earned 43.9 percent of the S&E degrees and 58.5 percent of degrees in non-S&E fields. Their participation varies greatly across S&E fields, being highest in biological sciences (51.1 percent) and psychology (72.6 percent); lower shares are evident in engineering (15.5 percent) and physics (15.8 percent); some fields lie in between, notably chemistry (40.4 percent) and mathematics and social sciences (both at 47.2 percent).

- Minorities have earned increasing numbers of S&E degrees. At the bachelor's level, minorities earned 10.7 percent of S&E degrees in 1991. The actual number of degrees awarded to minorities increased by 9.0 percent over the 10-year period from 1981 to 1991, a period when the number of degrees awarded to whites declined At the Ph.D. level, increases in percentage terms may obscure the small absolute numbers of awards to minorities in S&E fields. Increases of 5.3 percent in S&E Ph D 's to blacks in ten years, of 83.2 percent to Hispanics and 81.6 percent to Native Americans raised the number of degrees only to a total of 783 for these three groups in 1992, out of 14,262 Ph.D.'s to U.S. citizens in total.

- Despite increases in educational achievement, an important prerequisite for participation in many S&E fields, evidence indicates that underrepresented groups face other serious hurdles entering fields where their participation has been low. Cultural barriers appear to be inhibiting change.

- Women have increased their numbers in the workforce and in professional specialty occupations. In S&E they are concentrated in occupations within the social sciences and health assessment fields. In 1992 women represented 52.6 percent of those in all professional specialty occupations, but they make up only 8.9 percent of persons employed as engineers, 33.5 percent of those employed as computer scientists, and 27.2 percent of natural scientists.

- Minorities also remain underrepresented among scientists and engineers. For example, while 10.4 percent of the civilian labor force is black, they make up only 3.2 percent of the engineers and 4.2 percent of the natural scientists. Hispanics were 8.1 percent of the total labor force, but 3.2 percent of the engineers and 3.0 percent of the natural scientists.

- Fewer than one percent (0.6 percent) of the employed doctoral scientists and engineers report that they have a physical disability. This group is more likely to be employed part-time, rather than full-time, than is the group of all doctoral scientists and engineers (11.7 percent compared to 5.7 percent).

Diversity in the National Science Board

12 QUESTION: As you know, there has been a substantial amount of discussion in the last year or two about the lack of diversity on the National Science Board. We seem to be making some progress on that front with the recent confirmation of Dr. Shirley Malcom. We have 8 additional vacancies to fill this spring. While the nominations are the prerogative of the President, to what extent have you been focusing on this diversity issue with respect to recommendations concerning the composition of the Board? Have you discussed including representatives of industry on the Board?

ANSWER: The NSB is convinced that, in addition to personal excellence and achievement, the effectiveness of the Board is enhanced by a diversity in the origins, experiences, and disciplinary interests of its members. The need for greater representation of women and underrepresented minorities has been a special concern of the NSB A Board task committee solicited nominations for this year's vacancies from about 300 individuals, professional and educational societies and associations -- notably including organizations representing minorities, women, and handicapped persons -- and an announcement was published in the Federal Register. The criteria used to evaluate potential NSB nominations explicitly include balance in Board membership on the basis of representation of women and minority individuals.

Representation of industrially affiliated members is one of the criteria used by the Board in composing a balanced list of potential nominees to propose to the President. The NSB has always enjoyed participation by members with industrial affiliations. Four of the 24 members of the Board, and 23 former members of a total 140, including three who served as NSB Chairs within the last fifteen years, have had a primary affiliation with industry at the time of appointment.

Questions for the Record from Senator Mikulski

Graduate Education and Training

13 QUESTION: Math and science education has been the highest priority of mine from pre-school education all the way up through post graduate work. Education is empowerment.

Math and Science education is critical; and NSF, I believe, sets the standards for math and science learning at all levels. But, now we have students who were told they needed an advanced degree and now are trained Ph.D.'s with no job.

How do you think NSF can encourage change so that we educate students for real jobs in math and science?

How do you believe we can train our Ph.D.'s to be better prepared for the workforce?

ANSWER: Historically, advanced training for scientists and engineers occurred largely as a part of research programs, rather than through any strategic consideration of national needs for the science and technology workforce. As a result, the current system tends to perpetuate itself by producing scientists and engineers trained for increasingly narrow, and increasingly limited, research roles, predominantly in academe. This largely ignores the broader interests of our students and of the nation. To reform this system NSF aims for a flexibility in advanced training for scientists and engineers that will develop broadly educated, versatile people with the knowledge and skills necessary to address the needs of the nation in a rapidly changing world. We must rethink what it means to be a scientist, engineer, mathematician or technician. We need to encourage the development of broader skills, and the willingness to seek out other partners in the transfer of knowledge.

Roughly one-fifth of the support for graduate students in science and engineering comes from the Federal government -- either through research assistantships, fellowships or traineeships. This means that Federal agencies can make a major difference in graduate student education, if they choose to do so.

The solution to these problems does not begin at the graduate level. NSF is committed to improving education and workforce training at all levels, so that all Americans can obtain the skills and knowledge needed to succeed in the workplace. NSF can play a key role by supporting the development of quality science and mathematics education for all students at all levels through such means as curriculum reform, development of faculty and teachers, providing research experiences for students, and promoting learning connected to context, phenomena, and real-world problem-solving.

Let me give you a few examples of what NSF is doing to make a positive difference:

First, the broad priorities we have set in the research budget are important to note, including the increasing emphasis on areas of strategic priority to the nation. This encourages the research community to think more thoroughly about how they can contribute to addressing society's concerns. It also brings a more strategic focus to graduate education by attracting students to areas of increasing national importance.

Second, I think we will continue to see more programs that give students a broader-based educational experience while in graduate school. The most prominent examples of this are NSF's centers such as the Engineering Research Centers and the Science and Technology Centers. The centers give students an introduction to working on large, multidisciplinary problems -- often in collaboration with researchers from industry. This is a new experience for most students, and for many faculty members as well.

Third, NSF has also established a number of smaller programs that also move graduate training in this direction. Our divisions of Chemistry and Chemical Engineering have launched a joint program with the Council for Chemical Research to develop environmentally friendly methods of synthesis and processing. This program strongly encourages the principal investigators to seek out collaborators from industry.

The Engineering Directorate recently began a program called Grant Opportunities for Academic Liaison with Industry (GOALI). This program provides support for personnel exchanges between industry and universities and for collaborative research projects. NSF's other Directorates also have or are developing similar types of programs. These all give graduate students experiences that go beyond the traditional norms.

Again, these programs are small and reach only a small fraction of the people we support But I view them as the seeds of change in graduate education. And I think even in these times of budget stringencies, these types of programs should be given every opportunity to blossom and grow.

Public Understanding of Science and Engineering

14a QUESTION: **We have already seen how budget cutting has impacted science and technology. Look what happened to the Supercollider.**

It was important to basic physics research, but not everyone saw it that way. The Supercollider had its problems, but also no one could adequately articulate how it fit into our national strategy.

How do you believe NSF can facilitate the public's understanding of the importance of science and engineering?

ANSWER: According to the National Science Board's *Science and Engineering Indicators: 1993*, most Americans hold positive views of science and technology. The vast majority, however, feel that their scientific and technical knowledge is limited. There is broad agreement that economic, social, and political advantages exist in increasing the proportion of the population that is scientifically literate. The problem of achieving higher levels of scientific literacy requires both short-run strategies that broadly target the entire population, primarily through informal science education activities, and longer-term strategies that focus on our youth.

In the informal arena, NSF supports a wide variety of projects designed to reach the general public, informing them about science, mathematics, engineering, and technology (SMET). Some projects involving radio, television, and film have already demonstrated their ability to impact broadly on society. Examples in this arena include NSF's support of science and environmental coverage by National Public Radio and *IMAX* films (both with a strong impact on adults), as well as popular shows such as *Bill Nye the Science Guy* and the Saturday morning cartoon series, *CRO* (targeting children) Public understanding of science is also promoted through science museum and technology center exhibits and community-based groups, both of which often involve youth and adults in hands-on science activities. Informal science activities provide much needed exposure to scientific terminology that encourages further reading and study; helps the public understand the basic process of science; and increases awareness of those societal issues in which science and technology play a critical role.

Many times informal science projects complement and/or supplement formal education, promoting interest and deepening understanding in SMET fields. The effort for comprehensive reform of science and mathematics education at the K-12 level promises great pay-off in increasing literacy in science and technology. It promotes development of critical thinking skills and problem-solving, and promotes increased interest and study in these fields At the post-secondary level, NSF promotes increased scientific literacy of all post secondary students through programs aimed at strengthening education at the two-year and four-year institutions.

Enhancing the scientific and technical literacy of the American people is one of the keys to global competitiveness. Over time, a stronger education system will lead to informed citizens who are more confident in their knowledge, as well as more aware of issues in science and technology and their implications for our nation and society as a whole. NSF plays a leadership role in the science and math education reform effort. Through NSF's efforts which actively involves stakeholders across various sectors, it brings visibility to science and technology and increases awareness of their role in society.

14b QUESTION: How does NSF plan to get the word out on research results and exactly how science helps?

ANSWER: The Foundation has a comprehensive communications effort designed to inform a variety of different audiences about its activities and programs, major advances in science and engineering achieved with NSF support, and how science and technology contributes to quality of life issues and achievement of various national goals. For example, through National Science and Technology Week, NSF and corporate sponsors support the development and dissemination of education materials to thousands of elementary and secondary schools all across the country. These educational materials are designed to introduce students to the fun and excitement of science. In the ten years NSF has supported National Science and Technology Week, we have seen an ever increasing number of state, local, nonprofit and private sector organizations participate in local efforts to help interest young people in science and technology as well as raise the public's awareness of the impact of science and technology on everyday life.

NSF has a comprehensive outreach program designed to inform prospective participants about NSF programs and opportunities for support. These efforts are particularly directed at institutions which are not among the leading recipients of NSF funds. In addition, the NSF outreach efforts also focus on non-academic groups such as state government officials, business and industry groups, and local elementary and secondary schools.

Another important way that NSF distributes information about the research it supports is through the public affairs staff's media relations activities. These activities are conducted by a small group of communications experts comprised of professional writers, media relations experts, and audio-visual specialists. The group targets its efforts at print and electronic journalists.

The staff disseminates information about important research results--and the critical role which science plays in the quality of peoples' lives and the country's future--through a mix of written and audio-visual products, and special events. Written products include news releases, feature stories, tipsheets, publications, and speeches. Audio-visual products include radio and television background information kits, audio feature stories, video news releases, short film and video presentations on selected topics in science, engineering, and education. Combined with press conferences and briefings, media availability sessions, and other selected special events, the full breadth of its public affairs activities enables NSF to explain fully its mission and activities.

Many recent efforts have been noteworthy. For example, more than 125 journalists followed-up on an NSF press release about a company, supported by NSF's Small Business Innovation Research program, which developed an air conditioner that uses no chlorofluorocarbons in its cooling system.

In response to the January 1994 earthquakes in Northridge, Ca., NSF provided journalists various examples of NSF-supported earthquake research, examples which formed the basis of newspapers articles and television stories. These examples ranged from the development of high-tech hammers and sensors that help determine structural damage in reinforced concrete to new methods to evaluate and repair underground water, sewer, oil, and gas lines to new theoretical models used to improve the nation's emergency planning, disaster response, and residential rebuilding efforts. The Foundation has also featured research at the NSF-supported National Center for Atmospheric Research in Boulder, Co., which was designed to better understand and predict the atmospheric conditions that invite the formation of crash-causing ice on aircraft wings. Another example involved three University of Houston investigators who used supercomputers to find a previously hidden "back-door" entrance into an enzyme thought to play a significant role in Alzheimer's disease and glaucoma. This kind of discovery may lead to new drugs that have fewer and less severe side effects than current medications used to treat these and other debilitating ailments.

NSF and Industry

15a QUESTION: The Commission on the Future of the NSF stressed greater linkages and increased interaction between NSF and industry.

I am interested to know if NSF has improved its communication with industry.

How many of NSF's management staff have come to NSF from private industry and what are NSF's plans to increase this number?

ANSWER: Of the 113 senior executives currently at NSF, seven have come directly from private industry or from organizations closely affiliated with private industry, but many more have held industry positions sometime in their careers. In addition, four current members of the National Science Board and twenty-three former members have had a primary affiliation with industry at the time of appointment. Many others at the Foundation have been exposed to the industry perspective on NSF activities through collaborative research efforts and collegial affiliations on panels and at professional meetings.

NSF is increasing its contacts and partnerships with private industry and, as a result, hopes to identify and attract well-qualified individuals from that sector to management positions. An obstacle to such recruitment is the high compensation level of such individuals compared with their Federal counterparts. Although this imbalance also exists between academia and the government, the Foundation has successfully used the provisions of the Intergovernmental Personnel Act (IPA) to attract highly compensated executives from universities. Unfortunately, the IPA does not encourage such exchanges with much of private industry, specifically for-profit organizations.

15b QUESTION: What specific outcomes would NSF hope to achieve through its interactions with industry?

ANSWER: One of NSF's major goals is to foster collaboration among researchers in different disciplines and among universities, industry, national laboratories, and State and Federal Government agencies. Collaboration can open up new areas of inquiry; introduce fresh perspectives and new challenges; facilitate the application of new knowledge; and make more effective use of scarce resources. Collaboration is not easy, nor is it a panacea for all our problems. But it is a valuable tool, and one NSF is learning to use more effectively.

For example, NSF benefits from the involvement of representatives from industry in discussions related to the identification of problems and development of programs within the multi-agency U.S. Global Change Research Program. NSF involves private-sector firms in its evaluation of global change research proposals as external reviewers and as members of advisory panels. Through these interactions, industry is able to express their needs and priorities, have them addressed and incorporated into NSF's programs and, as a result, increase the benefit they receive from NSF-supported research.

A second goal of NSF's industrial interactions is to expand opportunities for the exchange of students and researchers between academe and industry. For example, one of the hallmarks of the Engineering Research Centers (ERC) program is the mutually beneficial relationship between students and faculty with industry. Students and faculty are exposed to industrial practices and needs, enhancing opportunities for training specifically relevant to industry. At the same time, industrial participants are exposed to more advanced concepts in research and technology developed at academic institutions.

For the university and the student, the benefits of this contact are immeasurable. It gives everyone involved a broader perspective on career opportunities, approaches to research, and of science and engineering generally. For industry, the benefits begin with the knowledge gained from the research, but they keep flowing for years into the future. When students who have participated in joint research activities move on to jobs in industry, they bring with them an understanding of industry and a respect for careers in industry that often in the past had been missing from the academic experience.

NSF also leverages its funding for projects with matching funds from industry. For example, in the Industry/University Cooperative Research Centers program, for every $1 provided by NSF, industry provides, on average, an additional $7. This greatly expands the scope and impact of NSF-supported projects. All of these interactions between NSF and industry foster efforts to transfer knowledge and technology resulting from fundamental research to successful applications in industry.

Academic Research Infrastructure

16 QUESTION: On the issue of facilities, there is so much infrastructure that needs to be reworked and I am concerned about how universities and especially small colleges will be affected without support for facilities. It will be difficult for our universities to conduct research and get people ready for jobs without this support.

Please tell the committee what NSF has planned for how to address this situation.

ANSWER: NSF plans to continue its program of competitive grants for academic research infrastructure. In this program we will emphasize research and research training facility renovations and the acquisition and development of research instrumentation. Also, in this program we will continue to separate the institutions into three groups, based on how successful they have been in obtaining funds from the NSF in previous years. That way, institutions will compete against like institutions. A certain percentage of the Academic Research Infrastructure Program funds will be allocated for each group. Therefore, small colleges will continue to have funds available for their infrastructure needs.

It is our plan to work with the Office of Science and Technology Policy, through the National Science and Technology Council, in order to lead a cross-agency effort that focuses on the modernization of the university and college research and research training infrastructure.

Women and Minorities in Science

17a QUESTION: I know there has been a campaign to engage more women and minorities into the field of science -- in physics, chemistry, engineering and mathematics.

But yet only about 8% of the doctoral degrees in physics being earned by women, and about 1 percent by African Americans.

What is NSF's campaign to recruit women and non-white individuals into the field of science?

ANSWER: NSF has identified several issues that are of particular concern relative to women, who are significantly underrepresented in the sciences, engineering and mathematics (SEM), including:

- the disproportionately high numbers of girls who lose interest in science during elementary and middle school;

- the low numbers of women who enroll in college-prep science and math courses in high school;

- the disproportionately low numbers of women entering undergraduate studies in SEM, particularly in the physical science, computer science, and engineering;

- the current low numbers of women completing SEM degrees at all levels; and

- the slow rate of women's advancement to senior rank and other leadership positions.

To reverse these trends, changes are needed. At the elementary and secondary levels, there must be significant changes in the ways science and math are taught to insure inclusion and participation of girls and young women and other underrepresented groups. This includes changes in the formal and informal interactions that support and develop their interest, understanding, and skills in science and mathematics. At the colleges and universities there must be changes in the cultures of SEM departments to improve the recruitment and retention of women and girls and other underrepresented groups, in SEM studies and careers. At all levels, there are barriers to participation for these populations that need to be addressed.

NSF's Programs for Women and Girls (PWG) is an effort begun in 1993 to help address some of these barriers. Components of this program are:

1. **Model Projects**, which encourage the design, implementation, evaluation, and dissemination of innovative, short-term, highly focused activities which improve access and/or retention of the target populations in SEM education and careers;

2. **Experimental Projects**, that support activities which create positive and permanent changes in the academic, social, and scientific climates which allow the interest and aptitudes of the target populations in SEM to flourish. This effort also supports projects which add to the knowledge base regarding interactions between gender or disability and the infrastructure of SEM.

3. **Information Dissemination Activities**, which accelerate efforts to increase the participation of these populations in SEM by encouraging widespread dissemination of information and strategies. This program supports activities which inform others of successful strategies which improve participation of or reduce barriers to these populations in SEM.

Underrepresented minority students drop out of school in significant numbers as early as the seventh grade. This is before formal study of science and math begins. Minority students need to have activities that first influence them to stay in school and then to continue to study science and math.

NSF is determined to ensure that individuals from all groups have an equal possibility of participating in SEM fields. NSF's goal is to substantially increase both the number of underrepresented minorities in NSF-supported fields receiving B.S. degrees and minority Ph.D. attainment by the year 2000.

These goals require projects with an emphasis on cohesive, collaborative strategies and specific outcomes. The following programs are designed to increase the enrollment and retention of minority students and produce measurable results:

- Summer Science Camps designed to increase student interest in and exposure to science and mathematics The program targets the middle school years where students begin the crucial study of science and mathematics and begin to explore career options.

- Partnerships for Minority Student Achievement designed to focus on the needs of underrepresented minority students and require the direct participation of the school system to support an integrated, systemic approach to enhancing all major components of educational system. This program is targeted at the precollege level.

- Comprehensive Regional Centers for Minorities designed to develop systemic approaches to increase the number of minority students enrolling in precollege courses which will prepare them for pursuing SEM undergraduate programs. This program focuses in regions of high minority population and must be developed through partnerships among several public and private organizations and community groups in the region.

17b QUESTION: What is NSF doing to combat biases against women and minorities in the scientific community? At NSF?

ANSWER: In addition to programs designed to bring more women and minorities into the field of science, NSF has policies to encourage full participation by women and minority scientists and engineers.

The most direct steps the Foundation can take within the scientific community involve areas in which NSF has control, such as the selection of peer reviewers and advisory committee members There are explicit policies at NSF that reviewers and advisory committee members should reflect a balance among several characteristics -- including geography, type of institution and organization, and underrepresented groups.

In addition, NSF has focused programs to provide special opportunities for women and minority researchers. Research Planning Grants enable those who have not had prior federal research support to develop a competitive research project. Career Advancement Awards support one-year projects to increase research capability and productivity. In the new program for Faculty Early Career Development, concern for balanced academic career development and emphasis on equitable participation by members of underrepresented groups will be part of proposal review and evaluation.

There are indirect ways, as well, that the Foundation can influence the community through the grant process For example, the Directorates for Biological Sciences (BIO) and for Social, Behavioral and Economic Sciences (SBE) have policies that address barriers to full participation at conferences, meetings and international congresses: programs recommending awards for meetings that do not include women among the invited speakers (in SBE, women and minorities) must describe actions taken by the principal investigator to identify qualified individuals and must provide an explanation for the omission.

NSF is also engaging the community in a dialogue on the climate and structure of the learning and working environment, by inviting letters and e-mail (eowomen@nsf.gov). The goal, outlined by the Director in a recent editorial, is to understand the barriers to pursuing careers, and to share ideas about how to address them (The Scientist, January 24, 1994).

At the Foundation, a task group on equal opportunity has been established to review the internal situation and recommend ways to improve the management and structure of continuing equal opportunity efforts. The issues that have been identified include equal opportunity organizational elements and effectiveness; events, programs and workforce equal opportunity training; NSF outreach efforts; career development; collection and analysis of data; and the workplace environment. The task group is seeking input from NSF staff as well as the NSF Committee on Equal Opportunity in Science and Engineering (CEOSE).

Evaluation of Research Programs

18 QUESTION: What evaluation criteria are used now to determine the quality and importance of an NSF research program? How is the decision made to terminate an existing program?

ANSWER: In general, NSF determines the quality and importance of existing research programs through a continuous and open process that receives input from the scientific, engineering, and education communities and the public at large. Choices as to what priorities to put on various areas are influenced by such factors as scientific and engineering readiness, technical feasibility, affordability, and balance with existing programs These priority-setting factors are debated continuously through such mechanisms as advisory committees, the National Science Board, professional societies, the National Research Council, and workshops and task forces such as the Blue-Ribbon panel on High Performance Computing In addition, standard Foundation-wide criteria for evaluating programs of research are being developed as part of the current internal strategic planning process.

NSF's programs change and evolve on a continual basis, depending upon the movement within the science or engineering field and national needs. Because of this, outright termination of a program rarely occurs. For example, over a ten year period, most programs within the Biological Sciences have changed in name and program content Programs may have been terminated, combined with others, or re-focused. Even in those cases where program titles may remain constant, program content does not. Those research areas that evolve and change do so as a result of continual qualitative peer-review based evaluation, special advisory studies, such as NRC, task forces, workshops, program status reviews, and, to some extent, the Committee of Visitors reviews every three years. Evolution in content keeps a field fresh and relevant.

Future of NSF

19. QUESTION: You have said that you understand the importance of government directing its investments in science toward "society's highest priorities."

As Director of what I believe to be the lead agency on science policy, what do you believe those priorities should be?

And what do you see as the future of NSF?

ANSWER: The best guidance for identifying priorities for science and technology programs can be found in the report "Technology for America's Economic Growth: A New Direction to Build Economic Strength" (released by the White House in February 1993). In this report, President Clinton and Vice President Gore outline three goals for the nation's science and technology policies:

- Long term economic growth that creates jobs and protects the environment.
- Making government more efficient and more responsive.
- World leadership in basic science, mathematics, and engineering.

These three goals set forth a national strategy for investing in research and education in science and engineering. The National Science and Technology Council is currently working to ensure that the government's portfolio of research and development investments is properly aligned with these goals.

NSF currently supports a range of activities that fulfill one or more of these goals simultaneously. For example, NSF's program in environmentally benign synthesis and processing supports cutting edge research in chemistry and chemical engineering <u>and</u> holds the potential to create new industries in "green manufacturing." The clean car program is another example of a set of activities that link fundamental research with challenges facing the industrial sector.

Similar examples can be found in the High Performance Computing and Communications (HPCC) Initiative. First, the "Grand Challenges" are employing HPCC technologies to explore the frontiers of science and engineering. Second, HPCC's investments in research and infrastructure are a key to industrial competitiveness. Third, a number of HPCC technologies have become key tools for reinventing government; for example, Mosaic, a software system developed at the National Center for Supercomputing Applications, is quickly becoming the principal tool used by Federal agencies, universities, and other organizations to disseminate information to the public.

These linkages and synergies can be found in many NSF programs, and they hold the key to the agency's future. I believe that a new paradigm is emerging for science policy in America A key event in the formation of this emerging paradigm was the recent "Forum on Science in the National Interest," where many in the community came to realize that the research enterprise would benefit tremendously from developing a sharper focus on the nation's priorities.

This emerging paradigm for science policy is based on four principles. The first of these is related to the issue discussed above: linking basic research more closely to its potential uses. For generations, our science policy has been based on a linear model that casts basic research and its uses as separate and distinct points on an assembly line. They were kept in isolation from each other and treated as if they were inherently incompatible.

The emerging paradigm takes a more dynamic view of this relationship and recognizes that the two should be integrated whenever possible. The Commission on the Future of the National Science Foundation underscored this point in its report, *A Foundation for the 21st Century*. It wrote: "Concern over technology application and competitiveness sometimes conjures a choice that budgeting is decided on either the criteria to please the scientists or to serve the public need. In reality these choices are congruent."

The second principle of this emerging paradigm for science policy and for NSF is preserving our "core values" -- namely, our commitment to excellence and creativity, as manifested through investigator-initiated proposals and merit review by scientific peers. We -- meaning NSF and the research and education community -- must continue to emphasize excellence in all our activities This emphasis on excellence and the spirit of competition is what has made our nation the world leader in science and technology, and it is what has enabled America to garner 71 Nobel Prizes in last 20 years, while no other nation has received more than 13.

These "core values" also include maintaining an adequate level of investment in high-risk areas of research with little prospect for a short-term payoff. The Vice President discussed this particular issue at the Forum. He compared our research enterprise to a library -- "except rather than just storing knowledge, it is constantly generating knowledge." He further stressed that this library, meaning our research portfolio, "must not have any empty shelves."

The third principle that shapes this emerging paradigm is continuing to invest in programs that facilitate cooperation and collaboration among industry, university, and federal agencies, across science and engineering disciplines, and with other nations. The benefits of these activities have become eminently clear, as the very nature of the research process thrives on input from a diversity of perspectives. These activities are also essential to promoting the transfer of knowledge between universities and industry. This is in keeping with the consensus view that "technology transfer is a contact sport" (to use the words of former IBM Vice President John Armstrong).

The fourth and final principle underlying this emerging paradigm is NSF's commitment to education and human resources. NSF is committed to improving education and workforce training at all levels, so that all Americans can obtain the skills and knowledge needed to succeed in the workplace and participate in our democracy.

These four key principles -- linking basic research more closely to its applications, preserving our core values, facilitating cooperation and collaboration, and leading reform and improvement in education and human resources -- provide vital touchstones that will guide the future of the National Science Foundation.

American Society for Engineering Education

1818 N Street, N.W.
Suite 600
Washington, D.C. 20036
Main (202) 331-3500
Fax (202) 265-8504

NATIONAL SCIENCE FOUNDATION
Reauthorization

The Engineering Deans Council (EDC) of the American Society for Engineering Education represents the more than 300 colleges of engineering in the United States.

The EDC believes that the National Science Foundation, particularly the Engineering Directorate, is working to strike an effective balance between its historic support for curiosity driven research and support for research aimed at meeting critical national objectives. While sustaining support for its broad research areas, the Foundation estimates that 75 percent of its requested budget increase for research in FY 1995 is for work in national strategic areas.

NSF is also providing real leadership to the academic community. In the Engineering Directorate, for example, the Engineering Research Centers program has become an international model for fostering interdisciplinary work by universities and industry. The Engineering Education Coalitions program, consisting of broad and diverse groups of institutions, is working to revolutionize engineering education and make it accessible and exciting for a wide array of students.

Given the Foundation's leadership in balancing priorities and helping the academic community better serve the nation, we make the following recommendations:

- We urge Congress to provide NSF with flexible authorization language. The more programs and activities the Foundation is required to do by statute, the less capability it has to provide leadership in new areas and under changing circumstances.

- We also request that Congress provide explicit permission to NSF to continue the Industry Experts In the Classroom program initiated under the Technology Reinvestment Program. (see attachment.)

- While it is valuable to re-examine the organizational structure of NSF on a regular basis, we recommend that any Congressional review look at a full range of models--including the existing structure--and provide full consultation with the academic community.

Industrial Experts In the Classroom

A Proposal for Reauthorization of the
National Science Foundation

One means of improving technology transfer and manufacturing-related education for the nation's engineering students is by encouraging appropriate industry experts to work in engineering colleges.

Congress has approved such a program -first as part of the Department of Defense FY 1992 authorization, and then as part of the FY 1993 Technology Reinvestment Project (TRP)--entitled Manufacturing Experts In the Classroom. We propose that the National Science Foundation be authorized to develop a program to continue this type of activity.

Under this proposal, an engineering college and a company or a group of small companies in the same industry would submit a joint application for support of an industry expert to work at the engineering college for at least one year. Personnel selected for such positions would have expertise in technology transfer and/or manufacturing, experience in managing technological innovation, demonstrated teaching ability and strong intellectual credibility (a Ph.D. degree would not be required). Manufacturing would include but not be limited to such areas as process engineering, systems integration and computer software technology.

The industrial expert would be required to teach at the undergraduate or graduate level and to engage in technology transfer activities. The individual should also participate in such faculty activities as curriculum development and academic affairs committees.

The purpose of the collaboration is to:

1.) improve the partnership between industry and academe;

2.) enhance the importance of manufacturing in all engineering curricula; and

3.) improve the transfer of knowledge to industrial use.

Support for the technology transfer/manufacturing expert would be shared through a 50/50 match between the National Science Foundation and the engineering college/industry partnership. Eligible partnerships could request grant funding of up to $100,000 per industrial expert for up to three years; partnerships would provide an in-cash or in-kind contribution at least equal to the amount of the grant requested. Grant funding could be used for salary and benefits for the industrial expert, as well as actual costs of the industrial expert's programmatic activities. No indirect costs, including administrative costs and purchases of equipment, could be charged to the grant.

The program would be administered through the Engineering Directorate of the NSF. The FY 1995 and 1996 authorization levels would be $5 million.

Senator MIKULSKI. This committee now stands in adjournment, subject to the call of the chair.

[Whereupon, at 11:45 a.m., the committee was adjourned.]

○

77-815 O - 94 (96)

ISBN 0-16-044416-0